MANATEE SPRINGS

ONSITE SEWAGE TREATMENT AND DISPOSAL SYSTEM

STUDY: Phase I

Final Report 11/24/04

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Florida Department of Health
Bureau of Onsite Sewage Programs

for

U.S. Environmental Protection Agency
Gulf of Mexico Program

Under cooperative assistance agreement
MX984888

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Chapter 1 Introduction and Summary

By Eberhard Roeder, Florida Department of Health, Bureau of Onsite Sewage Programs

Scope

This report describes the first phase of the Manatee Springs Onsite Sewage Treatment and Disposal System Study, also known as Karst Study. This study was funded by the U.S. Environmental Protection Agency's (EPA) Gulf of Mexico Program (GMP) ($50,436.00) and the Department of Health's (DOH) Onsite Sewage Research Fund ($86,407.76). Figure 1-1 shows the location of the study site, Manatee Springs State Park. The goals of the study were to investigate, in a karst environment, the impacts on groundwater quality by conventional onsite sewage treatment and disposal systems (OSTDS), consisting of a septic tank and drainfield. Karst is characterized by the presence of solution channels, sinkholes and springs in limestone bedrock. A layer of sand frequently covers the bedrock. These karst features allow rapid transport of water and contaminants between surface water and groundwater. Figure 1-2 shows areas in Florida where limestone is encountered within 30 feet of the ground surface and the results of this study are relevant.

Summary of Results

Two conventional septic systems with drainfields at the Magnolia II and Hickory campgrounds were studied. Magnolia represents a riverfront landscape position with a shallow water table, while Hickory represents a more upland/hammock situation with a deep water table. Ground Penetrating Radar surveys at both sites indicated the presence of paleo-sinkholes and solution pipes. Monitoring wells were installed into shallow groundwater downstream of the drainfields. One monitoring well at the Hickory site was installed into a solution pipe. Tracer tests, one at each location, consisted of injections of 50-gallon slugs of water containing two tracers, sulfur hexafluoride and fluorescein, into the drainfields. Monitoring wells were sampled for the tracers for up to a year. Sampling of the monitoring wells for nitrate, nitrite, ammonia, total Kjeldahl nitrogen (TKN), total phosphorus, and fecal coliform bacteria continued over a one-year period.

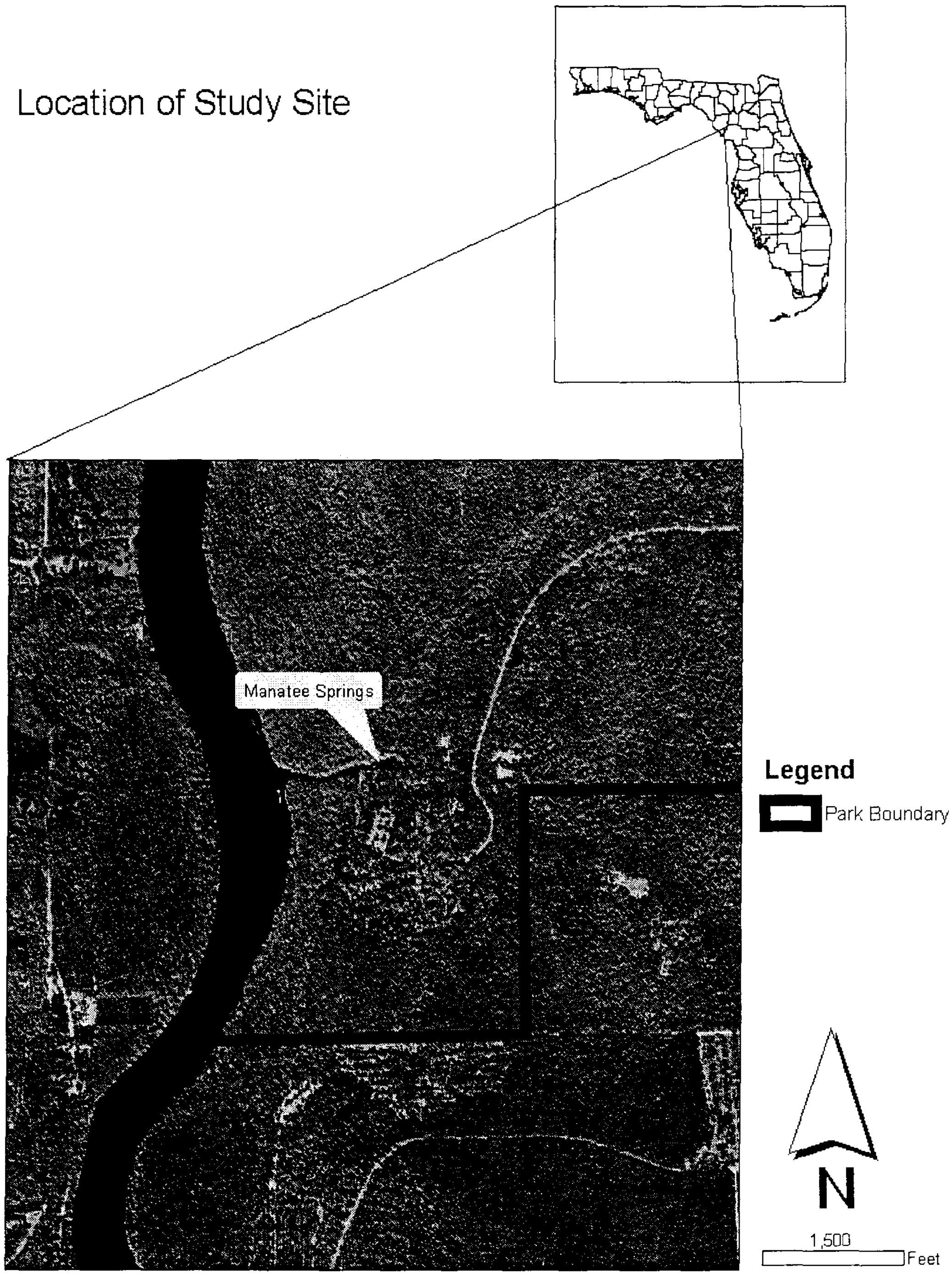

Figure 1- 1. Location of Study Site. Shown is the Southern Half of Manatee Springs State Park with the Spring and Spring Run.

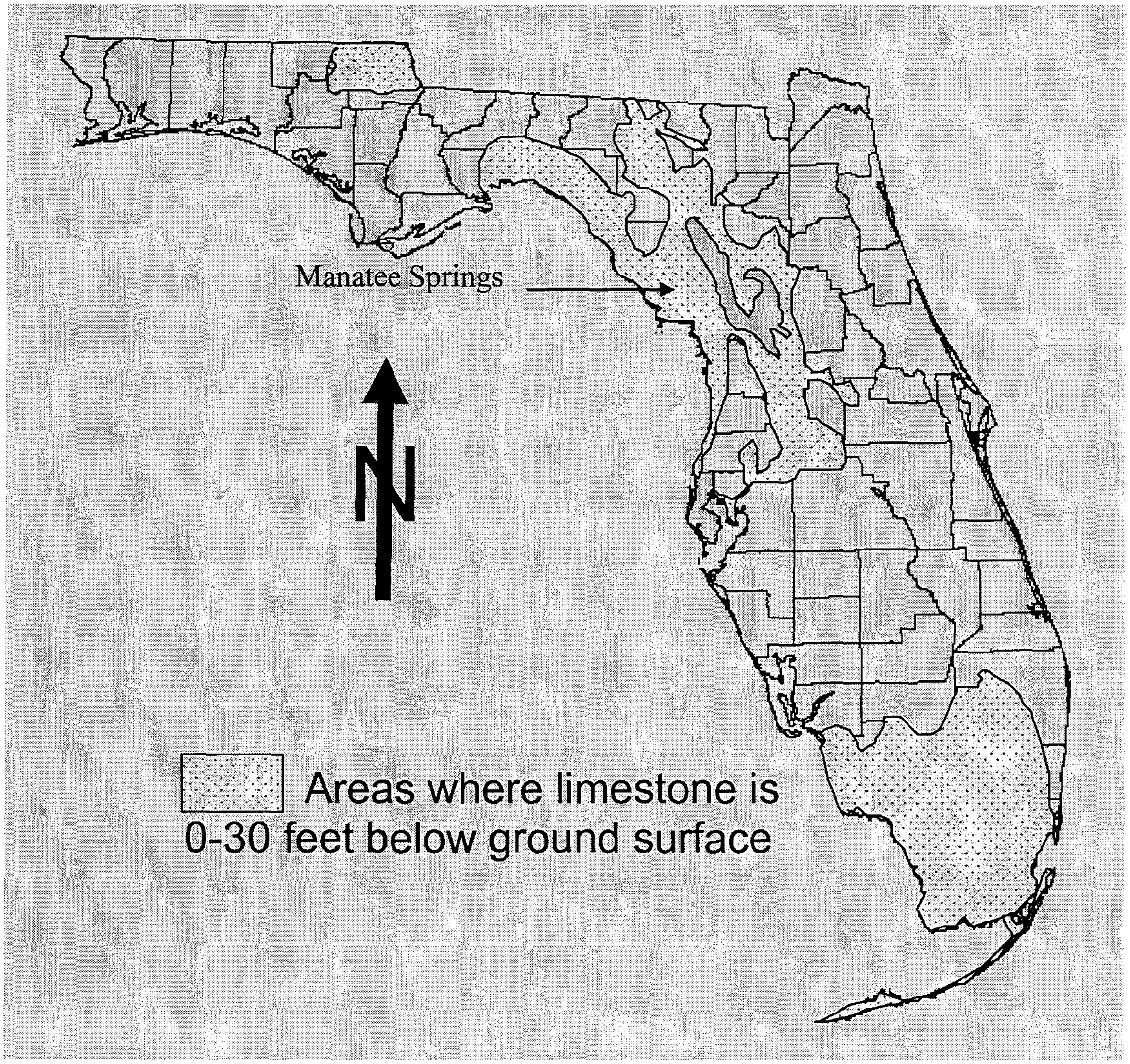

Figure 1- 2. Limestone within 30 feet of Ground Surface as Indicator of Karst Areas in Florida. Redrawn after Sinclair, W.C., and Stewart, J.W. 1985. Sinkhole type, development, and distribution in Florida. Map Series No. 110. Tallahassee, FL: USGS.

The results of this study confirmed that there are rapid connections between the near-surface drainfields and the underlying karst aquifer at both study sites. Tracer was observed at each site in monitoring wells within hours of the injection into the drainfields. Flow velocities, as determined by arrival times of peak tracer concentrations at individual monitoring wells, were in tens of feet/day. At Magnolia campground, flow rates varied from 5 to 100 feet/day and at Hickory campground they varied from 1 to 280 feet/day. Tracer from the Hickory tracer test was detected in Manatee Spring shortly after the beginning of the test.

On the other hand, the complexity of transport in karst, likely due to multiple types of porosity, was indicated by more than one peak in many monitoring well concentration time series and persistently high tracer concentrations up to a year after beginning the tracer test. The more volatile sulfur hexafluoride showed both earlier and later peaks than fluorescein.

Elevated nutrients were found in wells surrounding the septic systems with nitrate-nitrogen concentrations in impacted wells as great as 20 to 60 mg/L at both the Magnolia and Hickory sites. In the most impacted well at Magnolia, concentrations ranged up to 55 mg/L nitrate-nitrogen, 0.92 mg/L total phosphorus and 930 fecal coliform colony forming units (CFU)/100 mL. The most impacted well at Hickory was in a solution pipe, with concentrations ranging up to 56 mg/L nitrate-nitrogen, 4.9 mg/L total phosphorus and 99 fecal CFU/100 mL. The greatest concentrations observed in background wells were only 1.6 mg/L nitrate-nitrogen, 0.47 mg/L total phosphorus and less than two fecal CFU/100 ml. Elevated nutrient concentrations were found directly in the flow path of the effluent as indicated by the tracer experiments. The observed concentrations are far above the drinking water standard for nitrate (10 mg/L) and the EPA-recommended criteria for rivers and streams in the region (total phosphorus 0.04 mg/L and total nitrogen 0.90 mg/L).

Recommendations

The observed transport behavior in karst is not only applicable to onsite sewage and disposal systems but also to other systems that introduce water into the soil. The results of this and the subsequent phase of the study should be shared widely and integrated into the wider karst literature.

Implications for existing OSTDS density and setback regulations in karst areas are two-fold. The observed nitrate-nitrogen concentrations at Magnolia II show concentrations far in excess of drinking water standards at a distance of over 100 feet from the drainfield. At Hickory, nitrate-nitrogen concentrations above the drinking water standard were only observed within 100 feet of the septic system. The short travel times raise concerns that pathogens or soluble contaminants can impact drinking water wells very quickly, without warning. These issues can be addressed by changing required setback distances or by providing additional treatment.

The feasibility of specific karst regulations or the applicability of the rules for the Florida Keys to other karst areas should be reviewed, and a wider evaluation of the performance of existing nutrient-removing technologies should be used in consideration of nutrient regulations.

The second phase of the study will address groundwater quality after installation of nutrient-removing systems at Hickory and Magnolia II bathhouses. Several particular issues remain open and should be addressed to the extent feasible in the next phase to allow a better quantitative characterization of transport behavior in karst and OSTDS impacts on groundwater:

- The trends of nutrients and pathogen indicators in the observed groundwater quality over time.
- Estimates for mass balances of water, tracer, nitrogen, and phosphorus. This will allow an assessment of treatment effectiveness.
- A characterization of the hydraulic conductivity at the study site by either slug or pump tests, in addition to the existing core sample data.
- An estimate of the effective porosities of the limestone that contribute to transport.
- Effects of load variations between weekend and weekday use.

Structure of the Report

The report collates documents and information developed over the course of the project. The following is the overview of the sections, their content and institutional authorship:

1. Introduction and Summary(DOH)
2. Ground Penetrating Radar Study (University of Florida)
3. Well Installation and Background Data (DOH/Florida Geological Survey)
4. Groundwater Quality Monitoring (main report) (Florida State University/DOH)

History of the Project

The original project proposal was submitted to EPA-GMP in the summer of 1999. It was motivated by shellfish concerns in Suwannee Sound, which had just been reopened to harvesting. Due to complications associated with studying effluent from private residences, Manatee Springs State Park was selected as the site for the study during the last quarter of 2000. At this location an identified cave system was present that links groundwater to surface water, and it provided the benefit of relative isolation from other sources of contamination. At the selected drainfields, a ground-penetrating radar (GPR) study was performed by Dr. Mary Collins from the University of Florida in August of 2001. This study was used to guide monitoring well installation by identifying the location of solution pipes and paleo-sinkholes in the subsurface. Because of the necessity to permit, drill and case permanent monitoring wells, the installation of monitoring wells experienced delays. Ken Campbell of the Florida Geological Survey supervised the installation of the monitoring wells near the drainfields during June through August of 2002. Additional background monitoring wells were installed off-site during February of 2003, also by the Florida Geological Survey. During spring and summer of 2003, Harmon Harden and Jeff Chanton of Florida State University performed tracer tests and groundwater quality monitoring. Groundwater quality monitoring continued into 2004. Florida State University and DOH prepared the report during the second and third quarters of 2004.

Acknowledgements

The Bureau of Onsite Sewage acknowledges the contributions of all participants in the study. In addition to the staff involved in the study, this includes State Park staff, especially Manatee Springs State Park Manager Sally Lieb, and wastewater treatment design staff Chick Savering and Fred Hand. Suwannee River Water Management District staff, Ron Ceryak, David Hornsby, Tom Mirti, and Warren Zwanka, were always helpful with access to data and information.

The comments by outside reviewers on drafts of this report are gratefully acknowledged. These included Jennifer Gihring of the Florida Department of Environmental Protection, David Hornsby of the Suwannee River Water Management District, and Kevin Sherman of the Florida Onsite Wastewater Association. The Research Review and Advisory Committee of the Bureau of Onsite Sewage Programs provided discussions and feedback for drafts of the report.

Chapter 2 Ground-Penetrating Radar Investigations at Manatee Springs State Park

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Edited by Eberhard Roeder, Florida Department of Health, Bureau of Onsite Sewage Programs

Introduction

Ground-penetrating radar (GPR) surveys were conducted at two septic tank drainfield areas in Manatee Springs State Park in August 2001. The objective of these surveys was to locate depths to limestone and subsurface karst features (sinkholes and solution pipes), if present. Dr. Mary E. Collins, Professor of Environmental Pedology at the University of Florida, operated the GPR, and was assisted by Mr. Mike Tischler, Graduate Student at the University of Florida.

The Florida Department of Health (DOH) contracted the Environmental Pedology and Land Use Laboratory at the University of Florida to do two GPR surveys. One survey of a campground (Hickory Campsite) and one of the area between the bathhouse and the river bank at the Magnolia II campsite. The latter bathhouse, septic tank and drainfield are located on and in a mound, which is referred to as Dome hereafter. The purpose of the surveys was to determine the underlying stratigraphy of the areas of interest with GPR. It was most important to detect any solution features in the underlying limestone in the area. The GSSI-SIR-2000 unit with the 300-MHz and 500-MHz antennae was used in the investigations. Figure 2- 1 shows the locations of the GPR-surveys.

Background on Ground-Penetrating Radar

GPR is a geophysical instrument used to investigate subsurface features. The GPR system most commonly used in the world is the Subsurface Interface Radar (SIR) units manufactured by Geophysical Survey Systems, Inc. (GSSI) (www.geophysical.org). A 12 Volt DC battery powers it. The instrument collects real-time data. The transmitted radar signals can detect objects/features in Florida as deep as ~100 ft and as shallow as

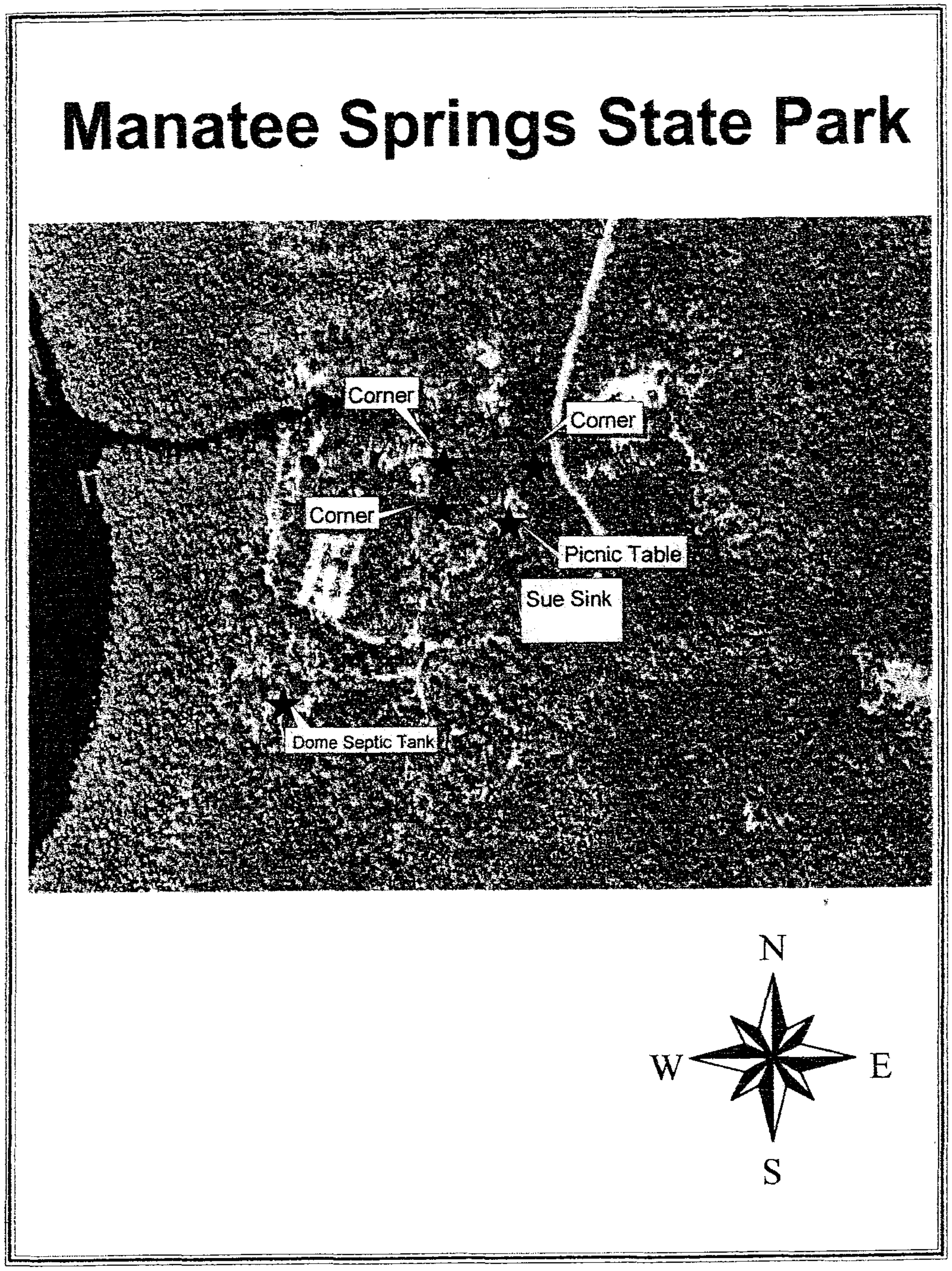

Figure 2- 1. Corner points of the GPR-surveyed areas at Manatee Springs State Park

one foot under optimum ground conditions and with the appropriate antenna. The depth of penetration depends upon the electromagnetic properties (principally conductivity) of soils and on the antenna frequency used. The depth can be estimated by using the equation:

$$D(m) = tp\ (0.15\ (Er^{1/2})^{-1})$$

where D(m) is depth in meters; tp is two-way travel time in nanoseconds; and Er is the dielectric constant of the material that is being penetrated. Velocity propagation and the Er are only approximations because factual information of the electromagnetic properties of most earthen materials is lacking. Also, most earthen material is not uniform in physical or chemical properties. Therefore, the Er changes. As a result the maximum depth of penetration is approximate.

Lower frequency antennae (e.g. 80 MHz) provide information at great depths, however they have a lower resolution of immediate subsurface features than higher frequency (900 and 1000 MHz) antennae. High frequency antennae produce better resolution and are used to discriminate closely spaced features at shallow depths. An antenna can be towed by hand or by a vehicle at speeds from ~2 to 5 miles/hr. Antennae have also been mounted on all terrain vehicles, boats, helicopters, skis, and snowmobiles.

The transmitting and receiving antenna is electrically coupled by the soil through which the pulses of electromagnetic energy travel. The radiation pattern is conical in shape with the apex of the cone at the center of the antenna. The GPR transmits repetitive pulses of short duration into the ground. When transmitted pulses of energy strike a change (interface) in the dielectric properties, a portion of the pulse energy is reflected back to the receiving antenna. The final result is a continuous profile record showing the location and depth of subsurface conditions and features.

The 300-MHz antenna was used at a setting of 120 ns (range) and dielectric constant of 5. This gave a maximum depth of penetration of 25 feet. All data was stored in the SIR-2000 control unit. In addition, the data was downloaded into a PC at the University of Florida for any necessary post-processing of the radar signals. Field notes are given in Table 2- 1. The data was interpreted to examine the depths to the argillic horizon and limestone. Computer diagrams (post-processing of the radar signal) of the transects and the associated subsurface features were created using the software RADAN and REFLEX. These data will be used to assist the Florida Department of Health and Florida State University in strategically locating monitoring wells around the onsite sewage system. All of the GPR images are included in the report and are labeled with subsurface features of interest.

Table 2- 1. Field Notes

Field notes – August 8, 2001; Manatee Springs State Park
Site 1 – Hickory Campsite Restroom Area
GPR parameters: Range = 120 ns; Dielectric constant = 5; Antenna frequency = 300 MHz
Flags along transect 25' apart; Flags between transect 20' apart
Transects
Transect 1 – file 1675
Transect 2 – file 1676 ½ transect, went to flag 4, aprox. at post #93 at campsite
Transect 3 – file 1677
Transect 4 – file 1679 flags 1-5
file 1681 flags 5-end
Transect 5 – file 1682
Transect 6 – file 1683
Transect 7 – file 1684
Transect 8 – file 1685 intersected by building, used standby
Transect 9 – file 1686 intersected by building, used standby
Transect 10 – file 1688
Transect 11 – file 1690
Transect 12 – file 1691
Transect 13 – file 1692
Transect 14 – file 1693 flags 1-6
file 1694 flags 6 – 2nd from end
file 1695 last two flags
Transect 15 – file 1697 add one click at end, forgot to click on last flag
Transect 16 – file 1698
Transect 17 – file 1700
Need to double check file numbers with SIR-2000 control unit
Site 2 – Magnolia II Dome septic tank area
GPR parameters: Range = 60, 80ns; Dielectric constant = 5; Antenna frequency = 500 MHz
9 Flags 20' apart along 1 transect; Start at crest of dome, end near river
Dome to River – 60ns, file 1702
River to Dome – 80ns, file 1704
Bad files: 1678, 1680, 1687, 1689, 1696 (ran over cable), 1699, 1701, 1703

Results

Hickory Campsite

The soils in the area surveyed by GPR are complex. The *Soil Survey of Levy County* (Slabaugh et al. 1996) has identified the soils in the Hickory area as Jonesville-Otela-Seaboard complex, 1 to 5% slopes (Figure 2- 2). The Official Series Descriptions of these soils are presented in Table 2- 2. The following is a summary of these soils:

> ***Jonesville*** *soil has an argillic horizon at a depth ranging from 20 to 40 inches. Limestone underlying this soil (depth to limestone ranges from 26 inches to 60 inches below the soil surface) has solution pipes 4 to 12 inches in diameter and filled with sandy loam or sandy clay loam material.*

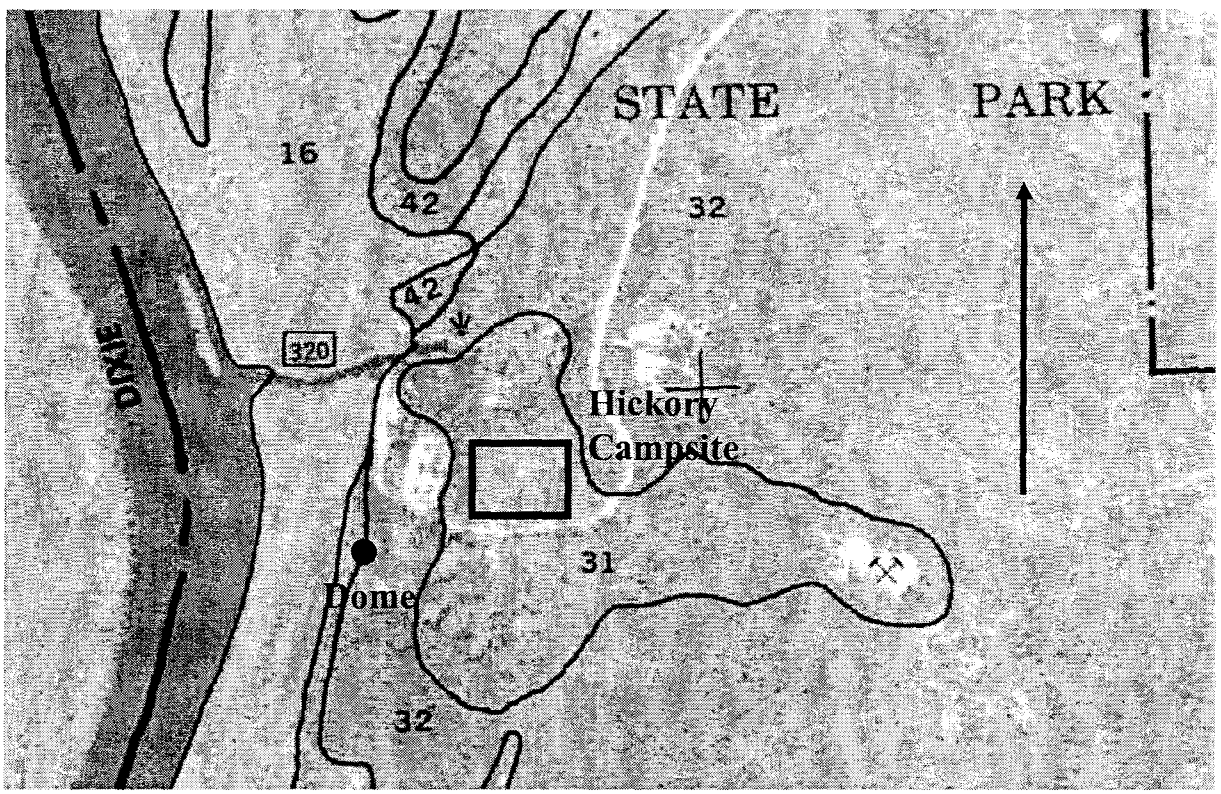

Figure 2- 2. Soil map with GPR-surveyed area at Manatee Springs State Park. (Additional information from the Soil Survey of Levy County (Slabaugh et al. 1996) added by E. Roeder: narrow North-South strip at the dome is 15=Holopaw-Pineda Complex, frequently flooded, 16= Chobee-Gator Complex, frequently flooded, 31= Jonesville-Otela-Seaboard Complex, 1 to 5 percent slopes, 32= Otela-Tavares complex, 1 to 5 percent slopes, 42= Ousley-Albany Complex, occasionally flooded)

Otela *soil has an argillic horizon at a depth below 40 inches. Limestone underlying this soil (depth to limestone ranges from 60 to 80 inches below the soil surface) does have solution pipes similar to the Jonesville soil.*

Seaboard *soil does not have an argillic horizon. It is sandy from the surface to the limestone. Limestone in this soil is very shallow (ranges from 10 to 20 inches) and can be hard limestone or it may contain solution pipes.*

The Hickory Campsite area was approximately 240 ft by 200 ft. The GPR transects were spaced 20 ft apart and the flags within the individual transects were 25 feet apart. There were a total of 17 transects. (Table 2- 1; Figures 2-4 through 2- 20). Also, a three-dimensional composite (a cube diagram) of all transects is presented in Figure 2-3.

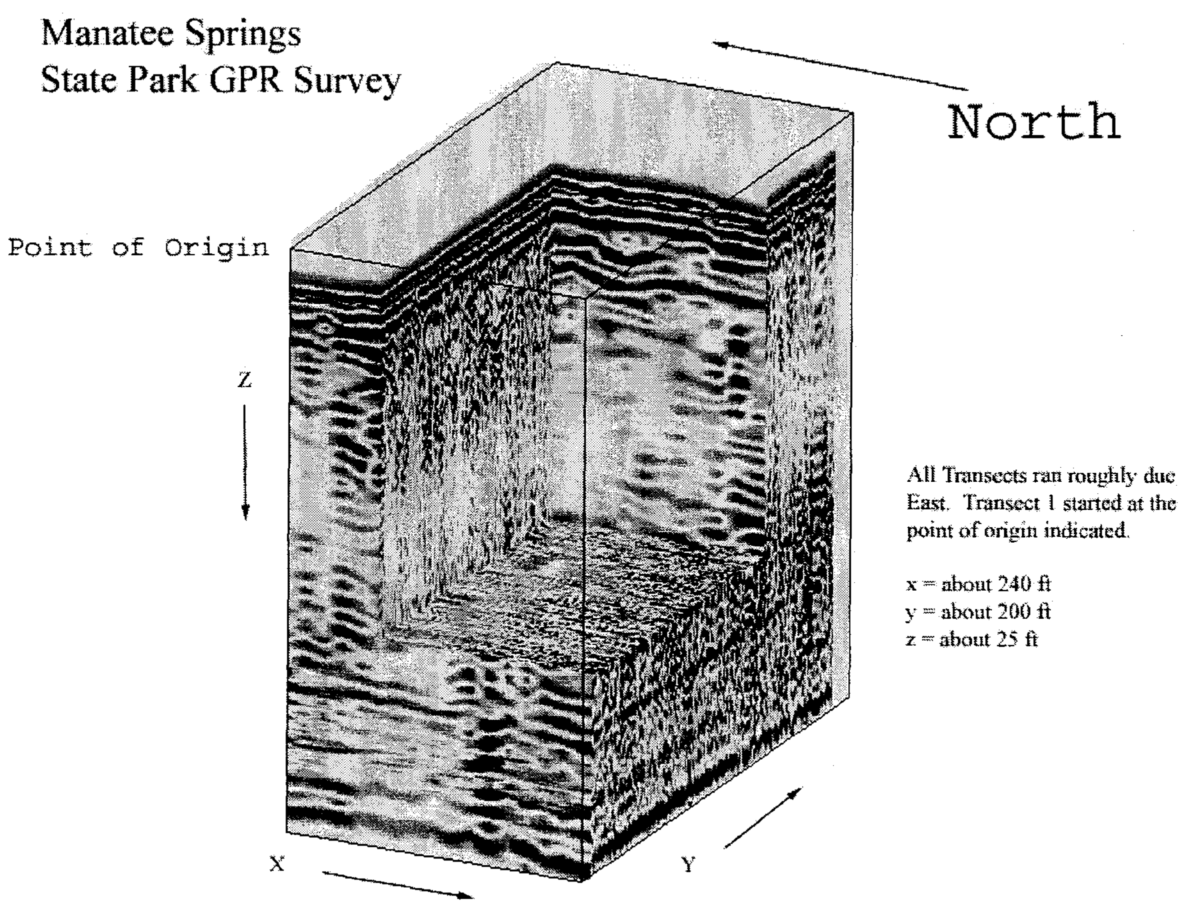

Figure 2- 3. Hickory Campsite 3D cube diagram

There are several areas that have been labeled on the printouts. No feature close to the surface was identified. The reason for this was that some of these features were due to the septic system at the Hickory Campsite bathhouse. Also, work had to be performed around campers and cars at the park, as well as around tree logs. No ground truthing could be done in the state park. Therefore, the features labeled are educated guesses based on experience in similar soils.

You will notice that several areas on the printouts were marked as solution pipes. Solution pipes (sometimes called solution holes) are small-diameter openings that can penetrate several feet. Many times these pipes are filled with soil material. Subsurface sinkholes are also marked. Without being able to ground truth these features, it is difficult to determine what type of material may be inside. Many of them are located below 10 feet. Areas where limestone is suspected are labeled as well.

Magnolia II Campground

The soils in this area are quite different than those at the Hickory Campsite (Figure 2- 2; Table 2- 2). Along the Suwannee River the soils are mapped as Chobee-Gator complex, frequently flooded. Near the Dome the soils are mapped as Holopaw-Pineda complex, frequently flooded. All of the soils are poorly to very poorly drained and no limestone is mentioned. The Official Series Descriptions for these soils are included in Table 2- 2.

The two GPR transects at the Magnolia II Dome or mound, on which the bathhouse is located, were done with the 500-MHZ antenna (Table 2- 1). The first GPR transect was done from the Dome to near the river at 60ns (penetrated to a maximum depth of 12 feet). The second was from near the river to the Dome at 80ns (penetrated to a maximum depth of 16 feet). There are two areas of interest on the GPR data (Figures 2- 21 and 2- 22). The one is located on the Dome and could be an artifact of the construction of the Dome showing the original soil surface. The other is located at 140 feet from the Dome. This feature could be a solution hole. Again, ground truthing is necessary to confirm these observations.

Summary

Ground-penetrating radar (GPR) was used at Manatee Springs State Park in August 2001. The purpose of the GPR surveys was to determine the underlying stratigraphy of the Hickory Campsite and the Dome septic system areas with GPR. It was most important to detect any solution features in the underlying limestone in the area. The GSSI-SIR-2000 unit with the 300-MHz and 500-MHz antennae was used in the investigations. Seventeen GPR transects were made at the Hickory campsite and two were made at the Dome (Magnolia II). The soils in the area are complex with varying depths to limestone. Possible sinkholes and solution pipes are identified on the GPR data. No ground truthing was allowed in the Park the day these data were collected. Therefore, it is important to confirm the presence of these noted features at a later time.

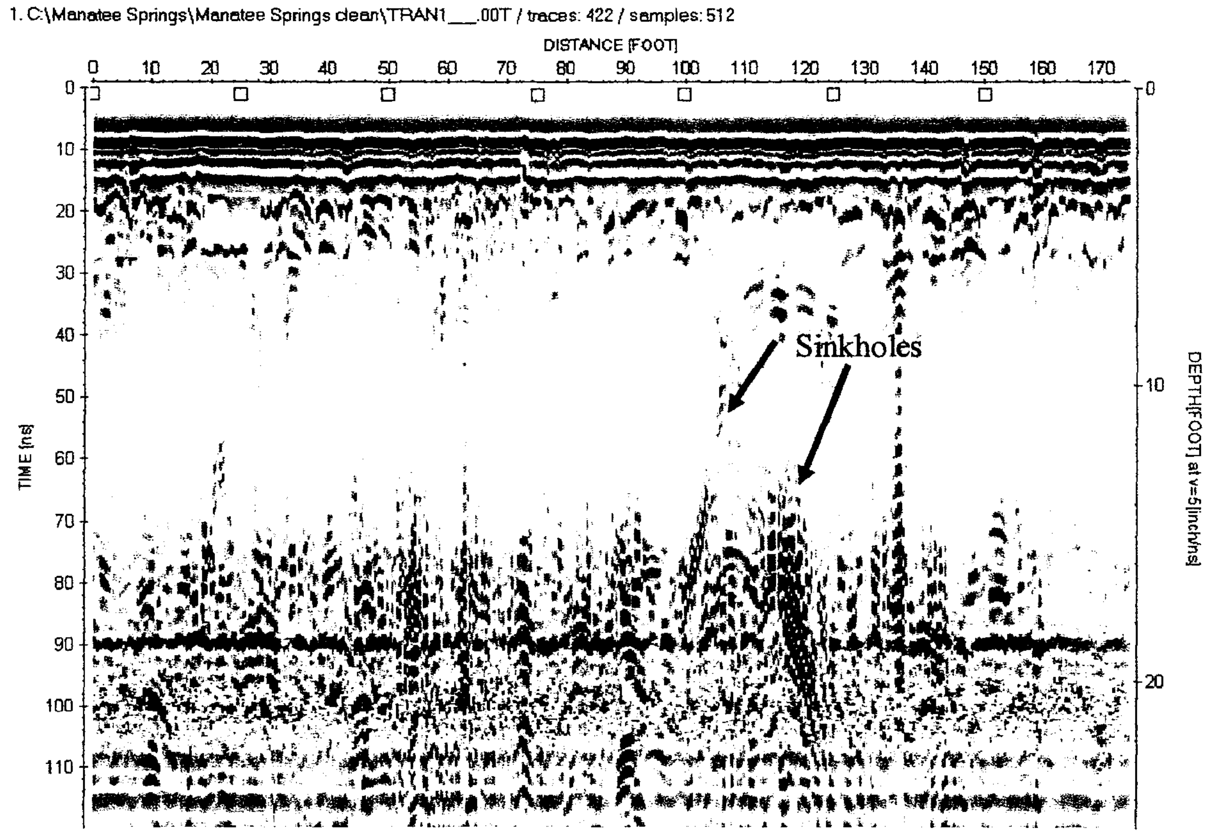

Figure 2- 4. Hickory Transect 1

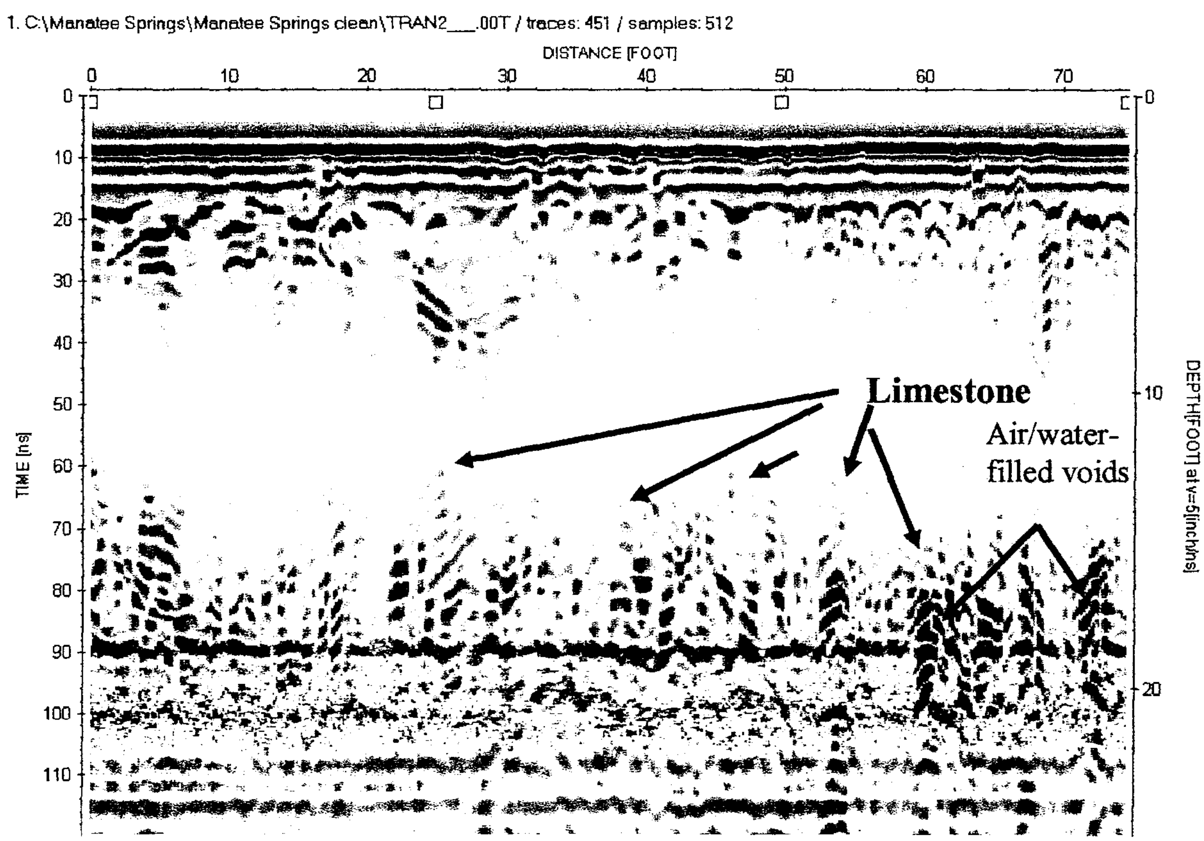

Figure 2- 5 Hickory Transect 2

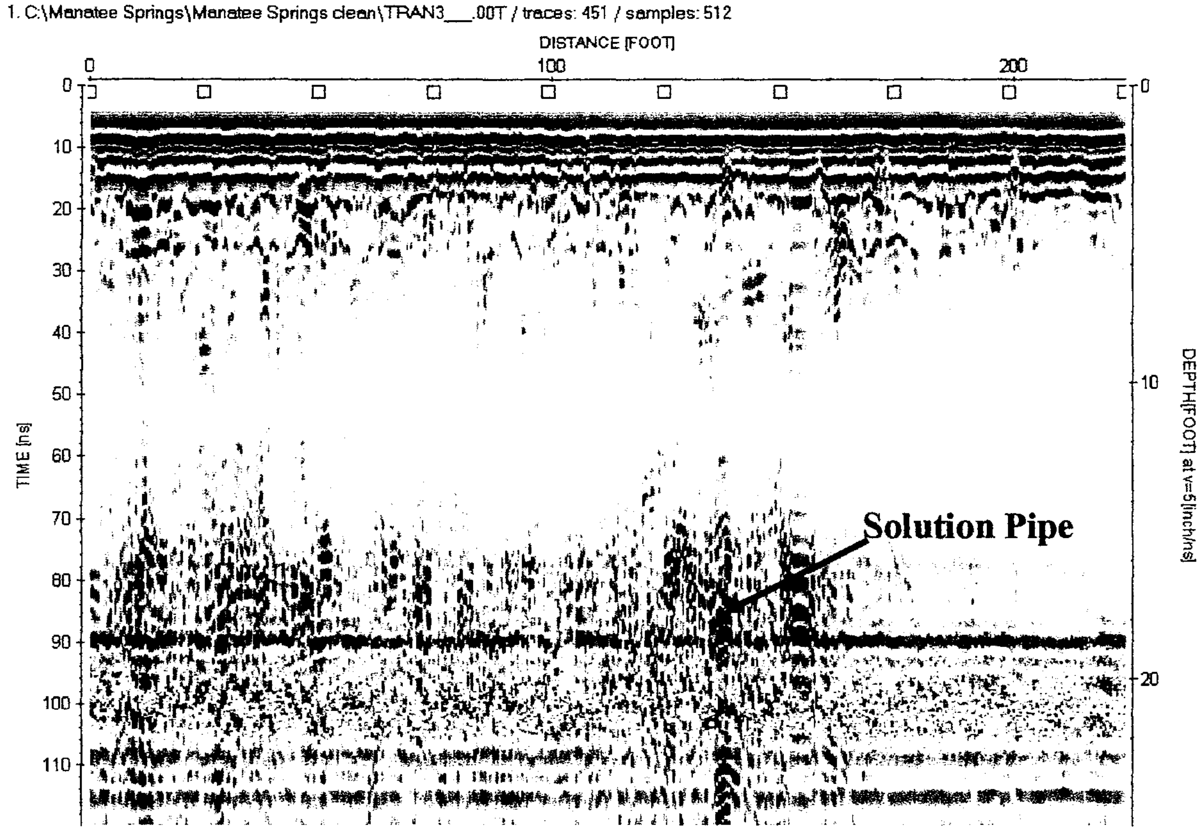

Figure 2- 6. Hickory Transect 3

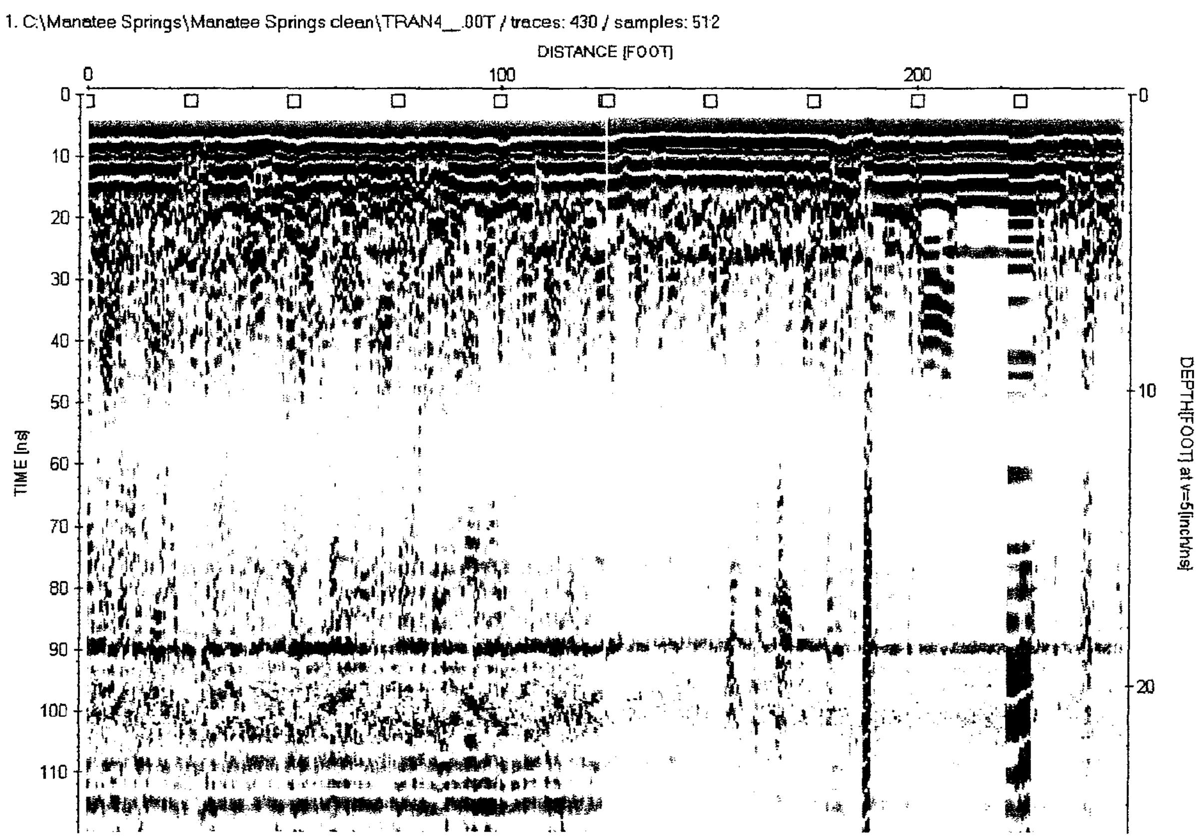

Figure 2- 7. Hickory Transect 4.

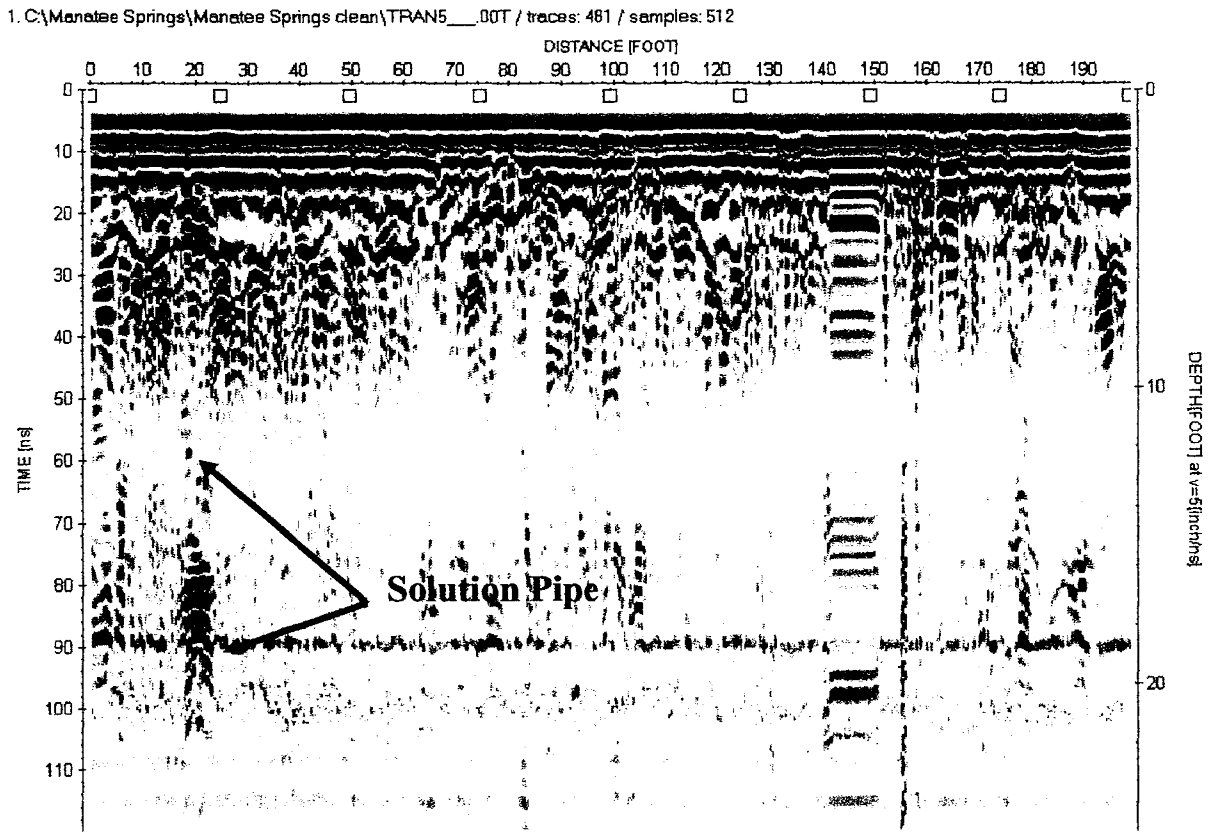

Figure 2- 8. Hickory Transect 5

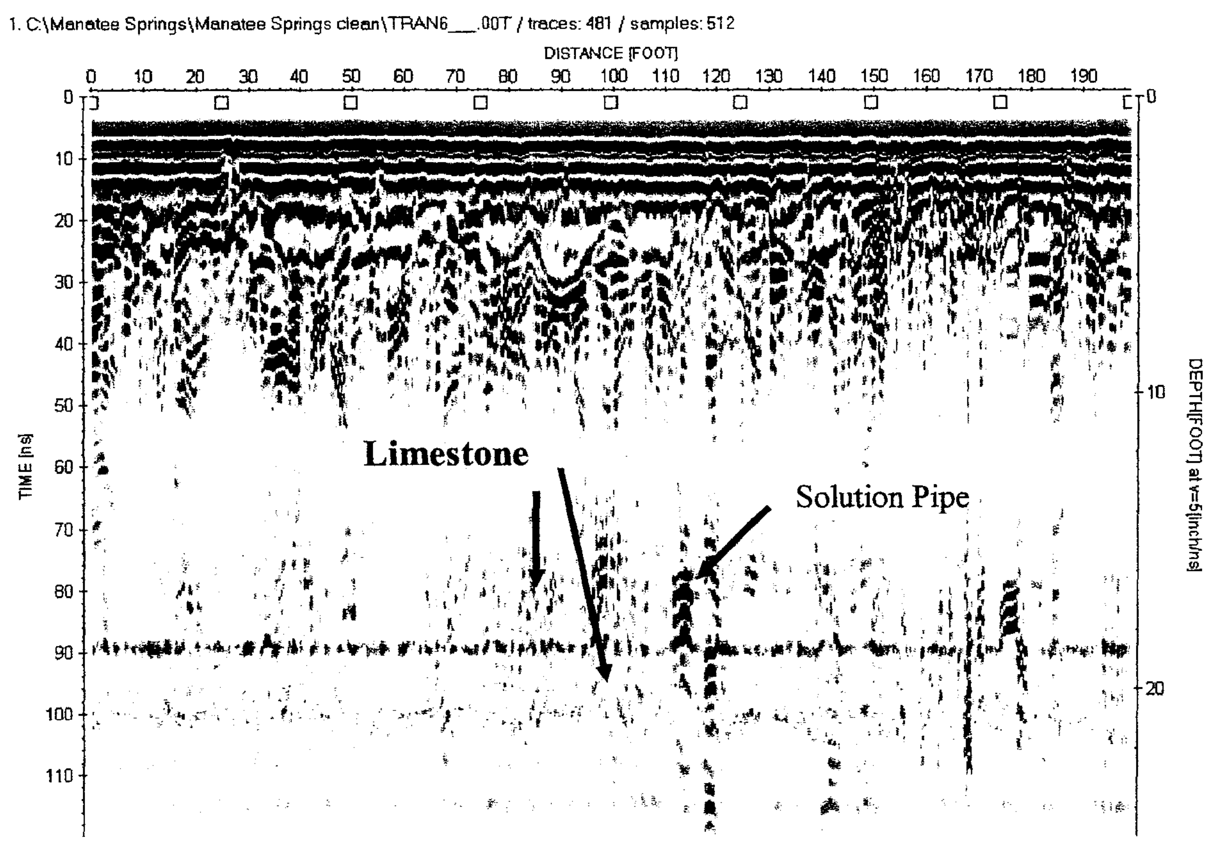

Figure 2- 9. Hickory Transect 6

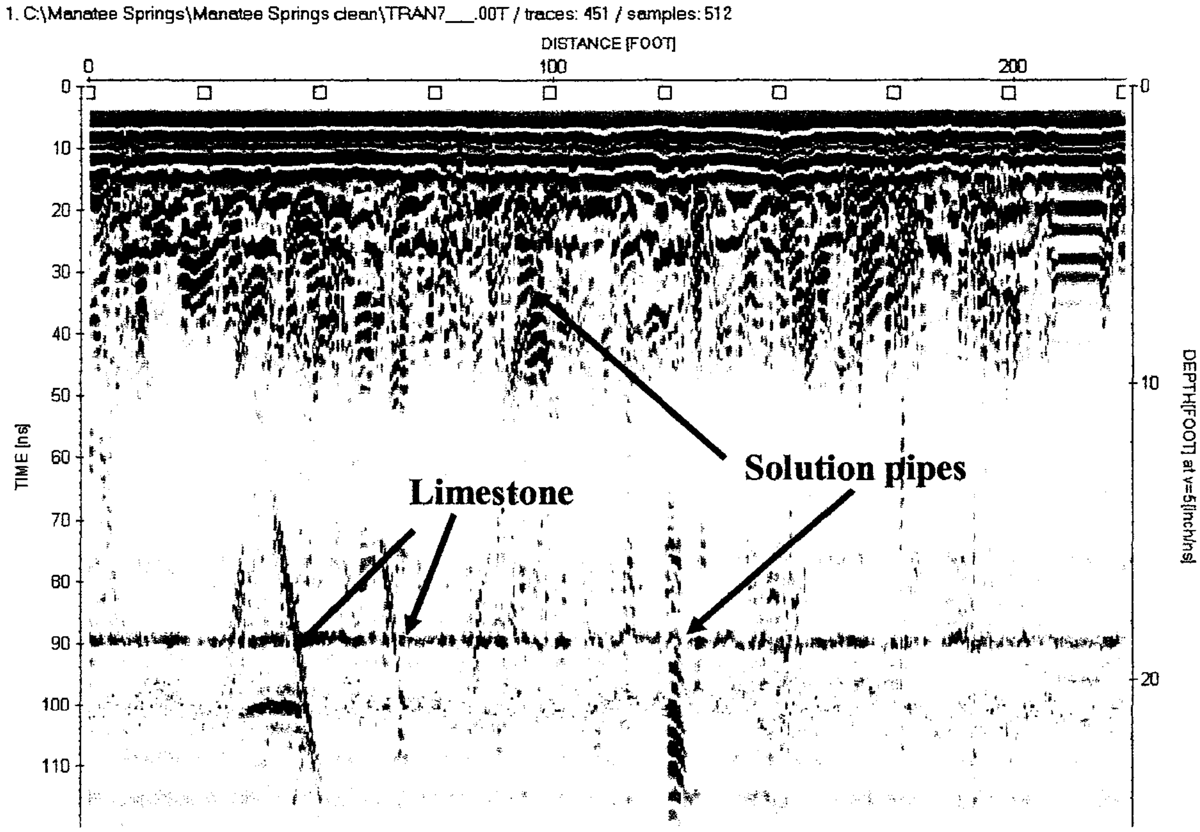

Figure 2- 10. Hickory Transect 7

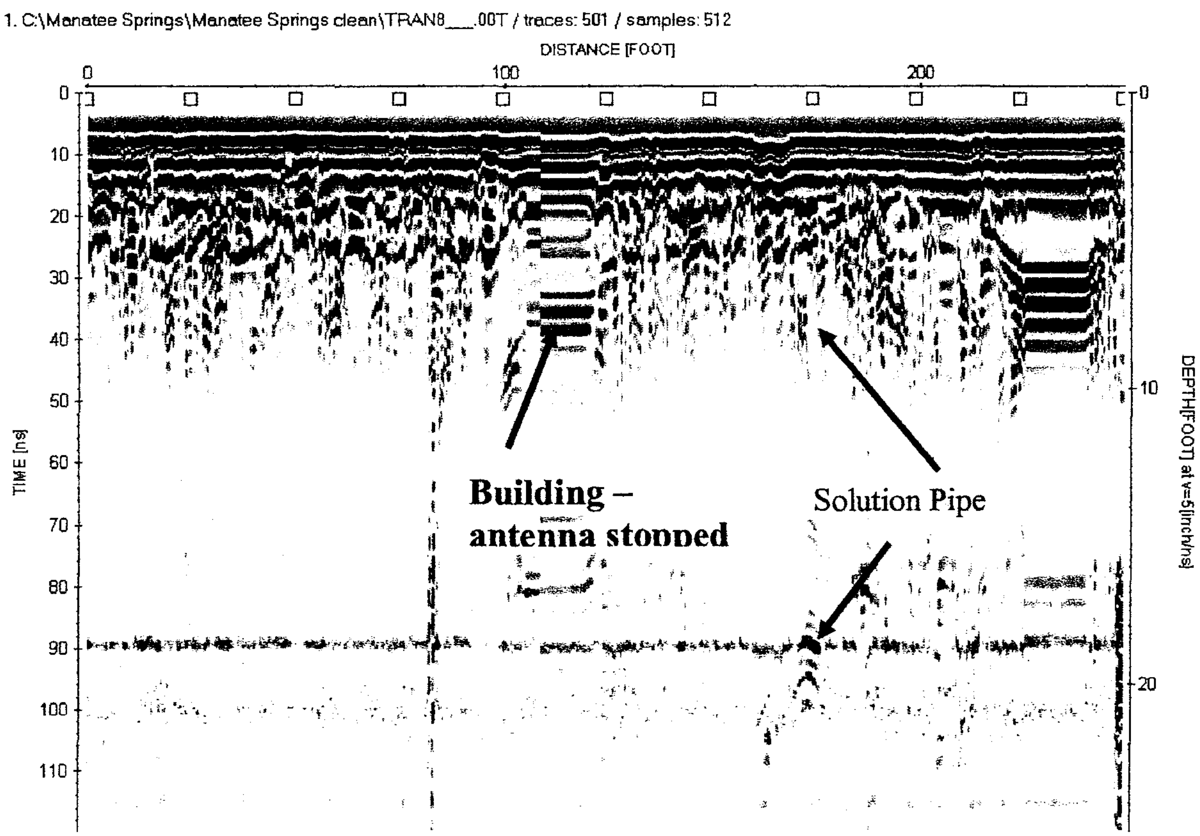

Figure 2- 11. Hickory Transect 8

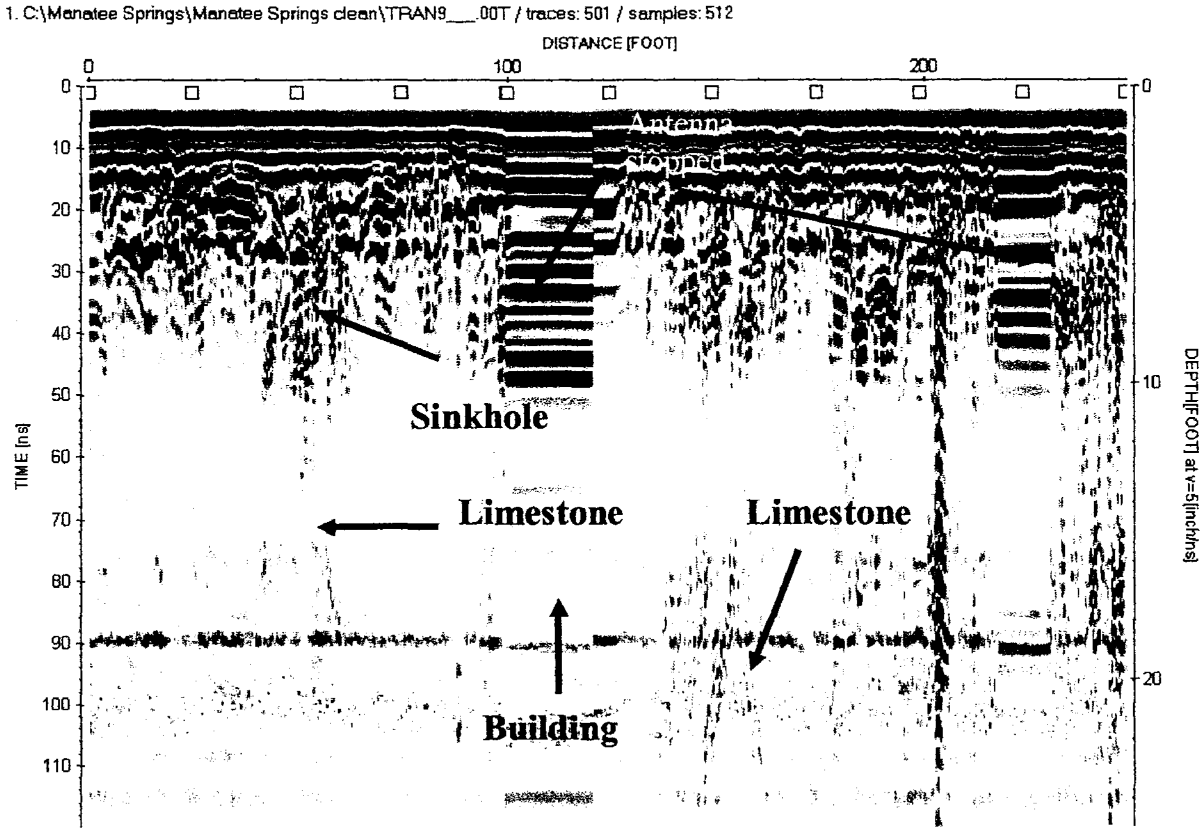

Figure 2- 12. Hickory Transect 9

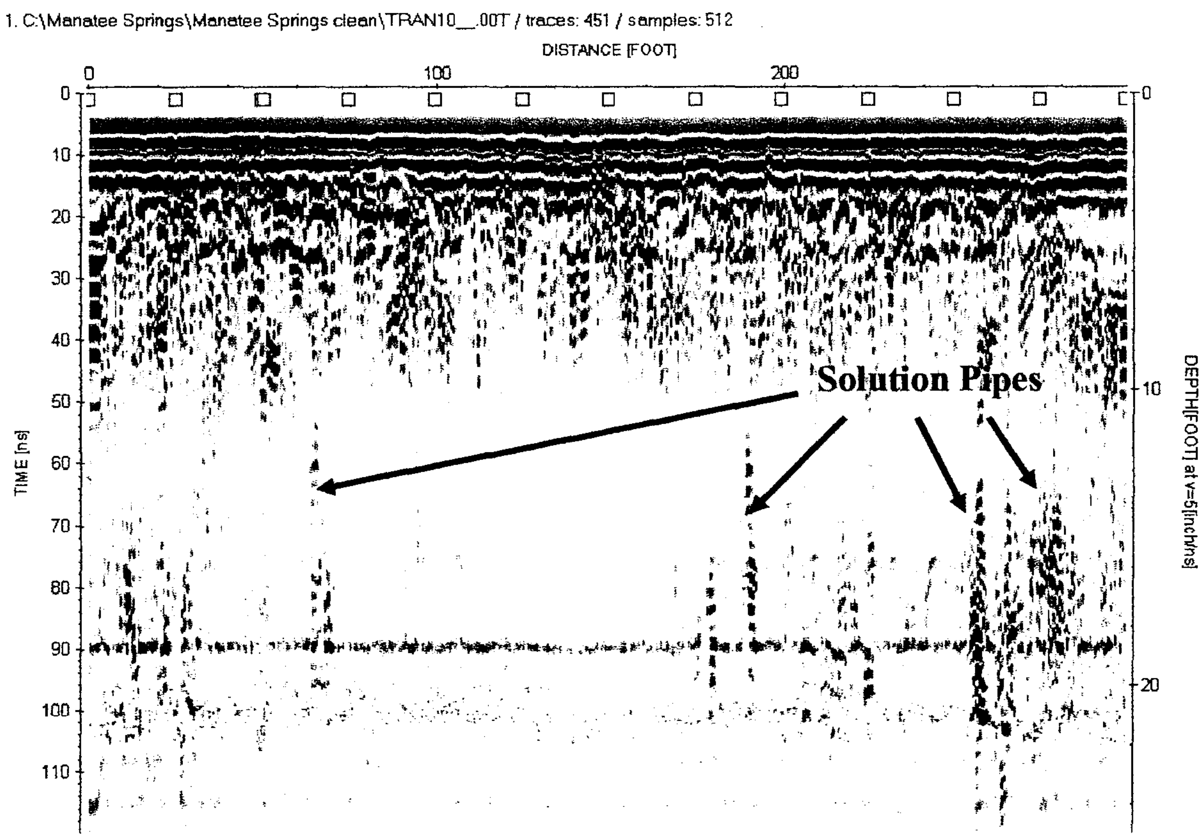

Figure 2- 13. Hickory Transect 10

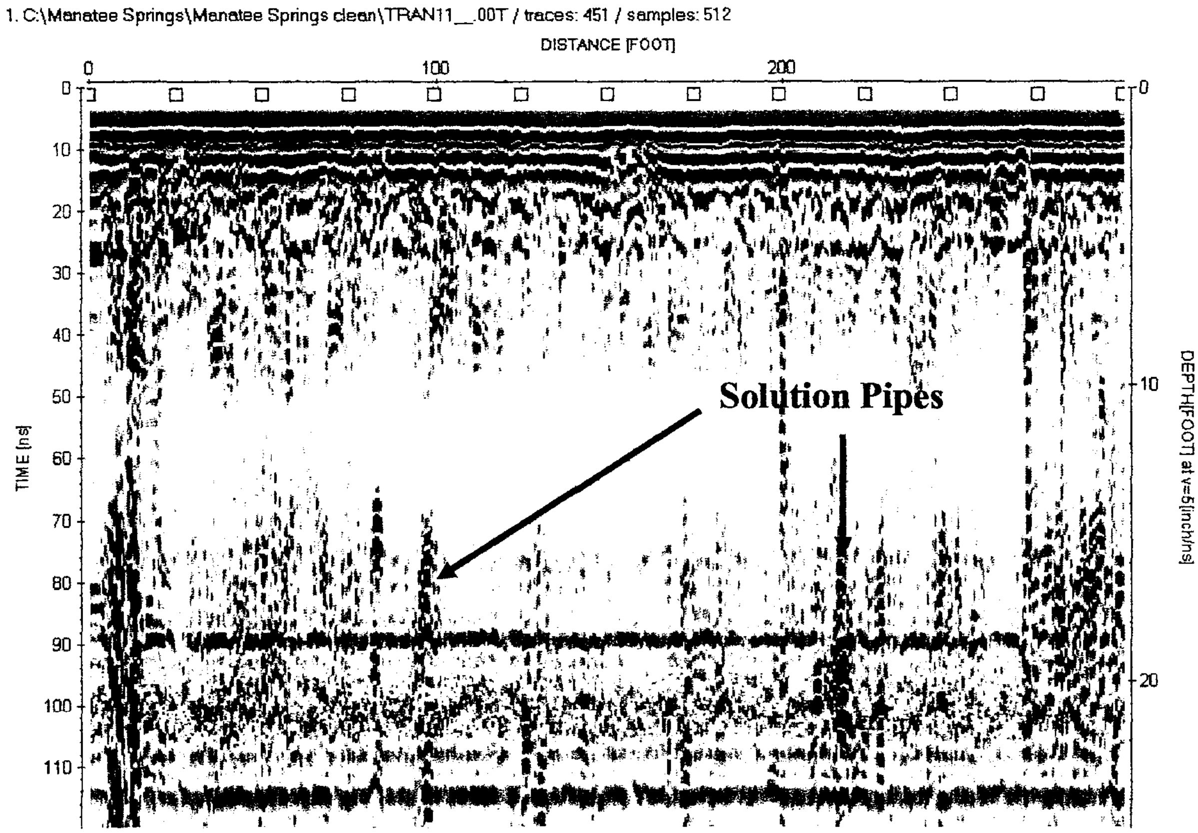

Figure 2- 14. Hickory Transect 11

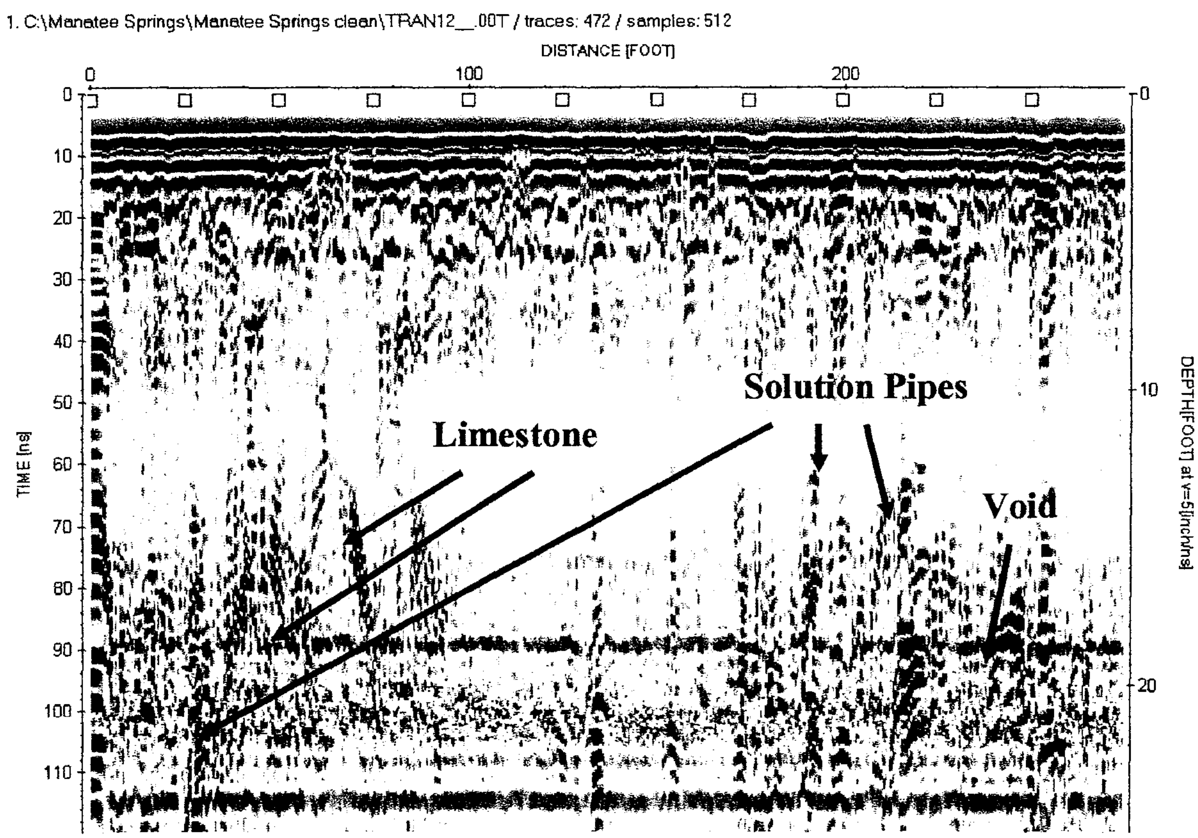

Figure 2- 15. Hickory Transect 12

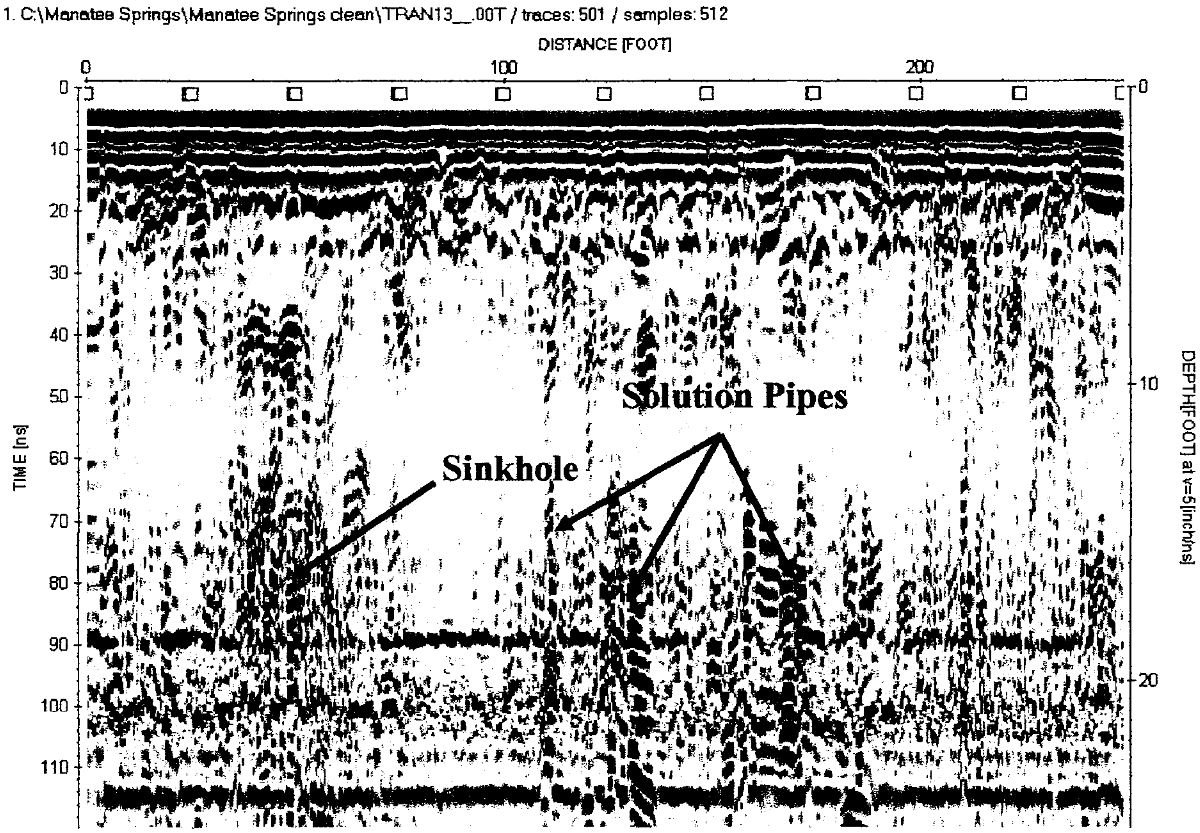

Figure 2- 16. Hickory Transect 13

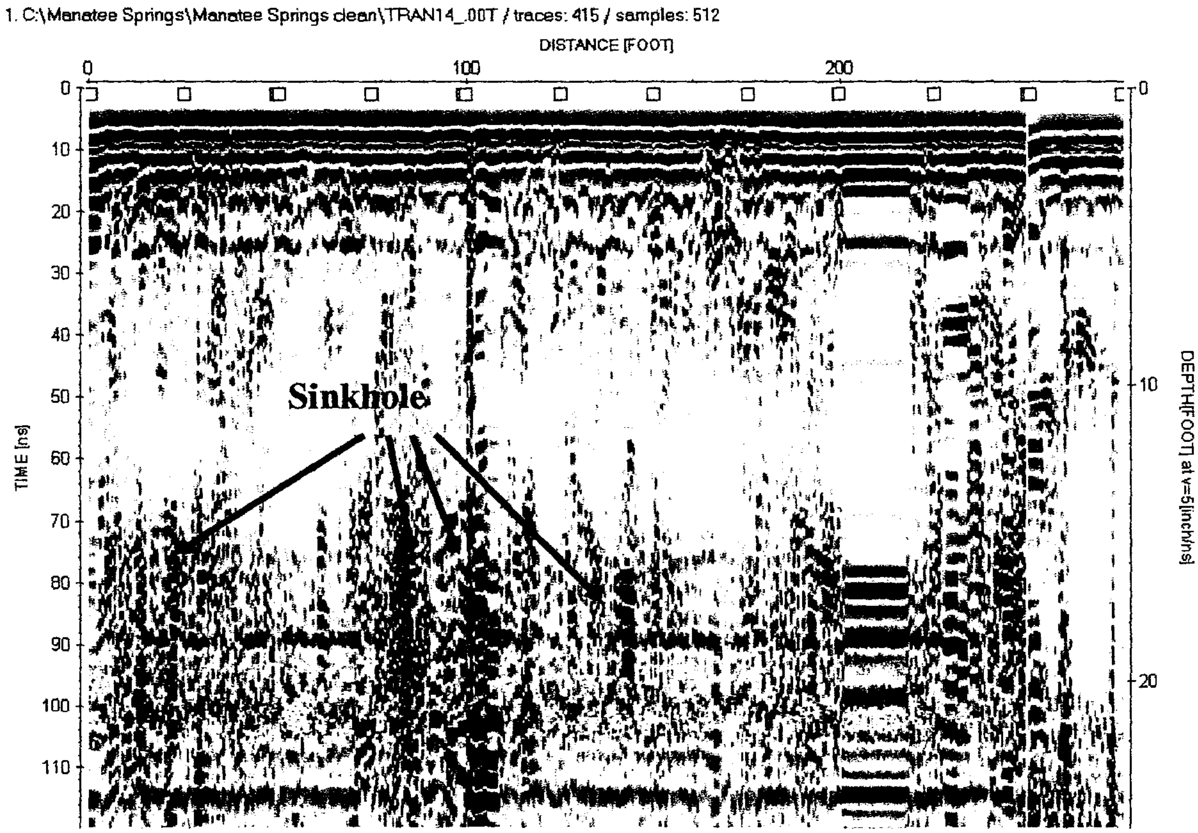

Figure 2- 17. Hickory Transect 14

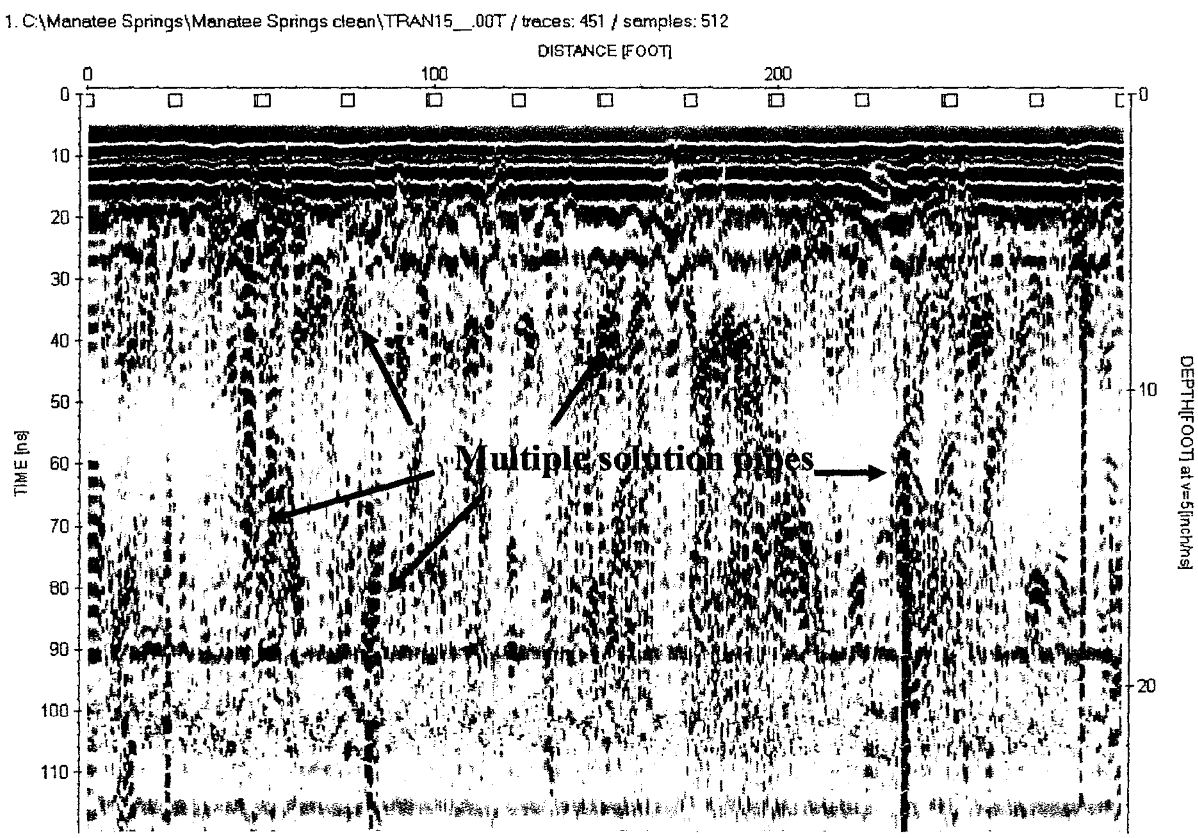

Figure 2- 18. Hickory Transect 15

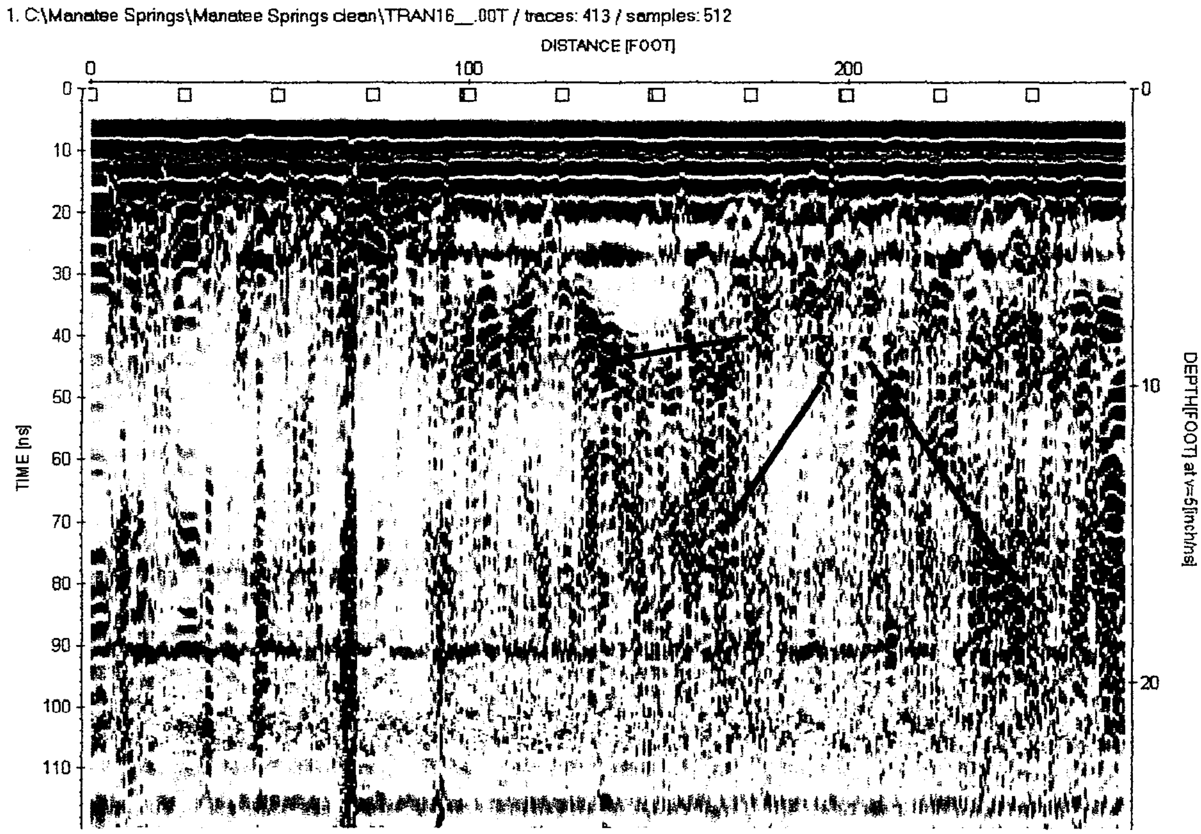

Figure 2- 19. Hickory Transect 16

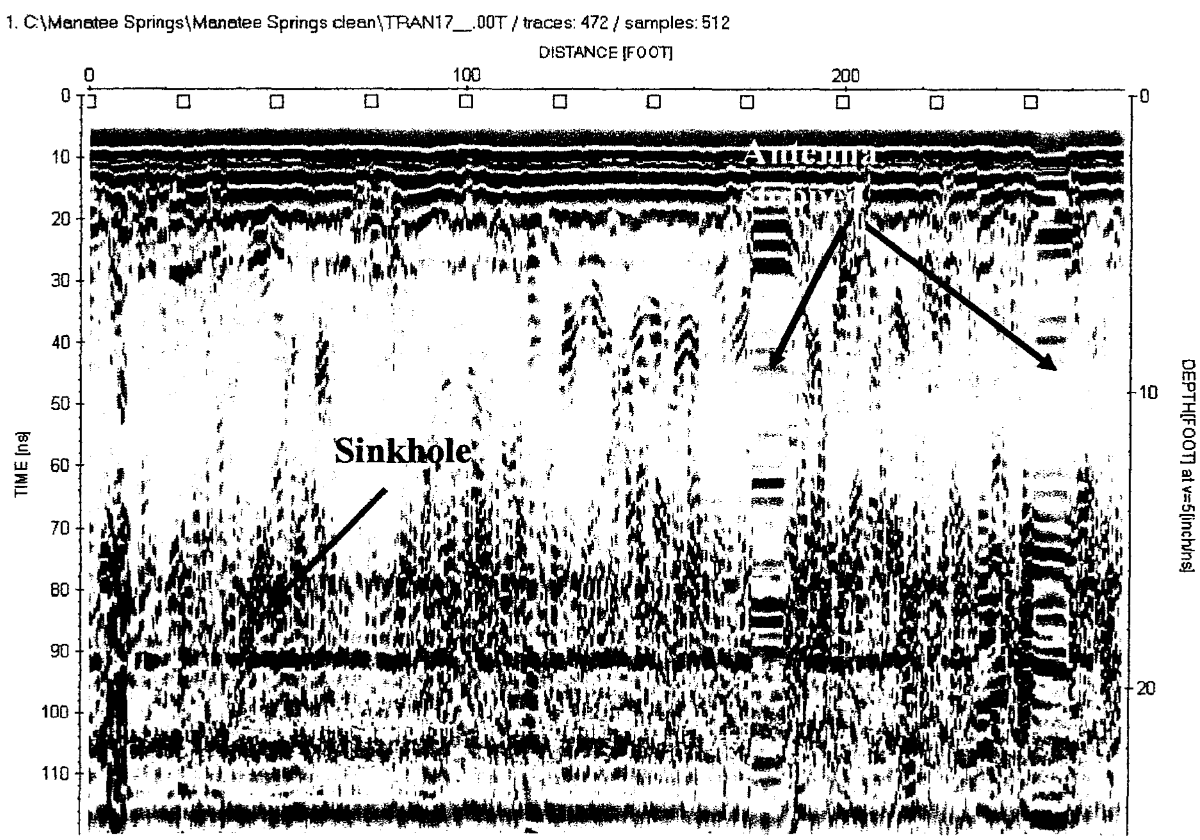

Figure 2- 20. Hickory Transect 17

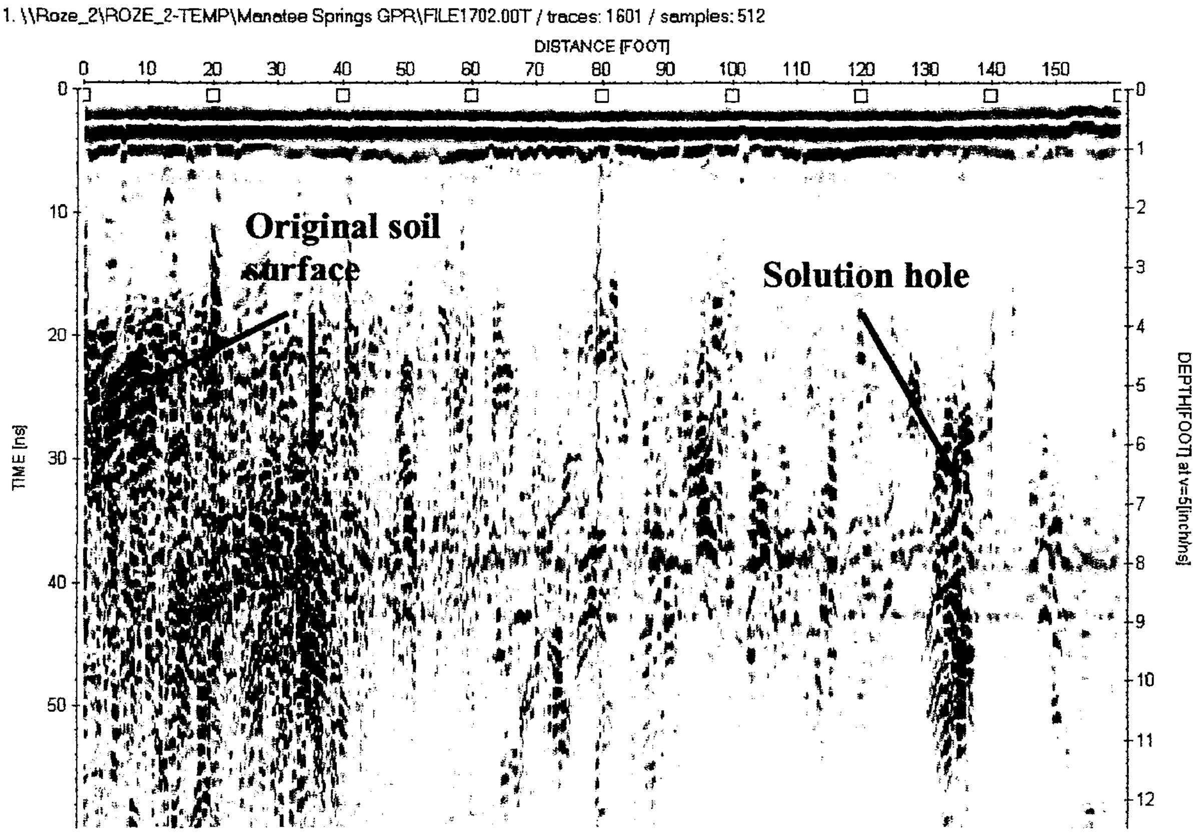

Figure 2- 21. Magnolia Transect 1 from Dome to River

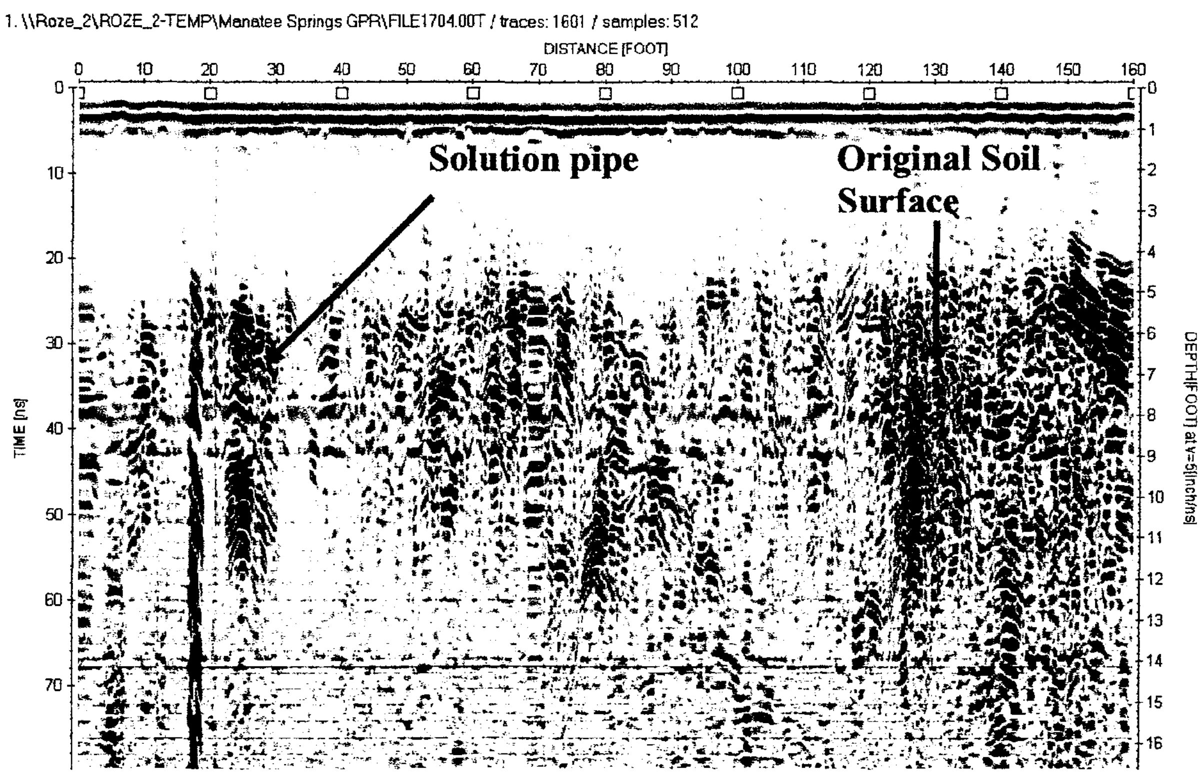

Figure 2- 22. Magnolia Transect 2 from River to Dome

Table 2- 2. Official Soil Series Descriptions (cf. Slabaugh et al. 1996)

In the order: Jonesville, Otela, Seaboard, Chobee, Gator, Pineda, Holopaw

Jonesville

LOCATION JONESVILLE FL
Established Series
Rev. BPT:AGH
1/93
JONESVILLE SERIES

The Jonesville series consists of moderately deep, well drained soils that formed in sandy and loamy marine sediments overlying limestone. They occur on ridges and gently undulating uplands in the hyperthermic region of Florida. Slopes are 0 to 5 percent.

TAXONOMIC CLASS: Loamy, siliceous, hyperthermic Arenic Hapludalfs

TYPICAL PEDON: Jonesville sand in a forested area. (Colors are for moist soil.)

A--0 to 7 inches; dark gray (10YR 4/1) sand; weak fine granular structure; very friable; common fine and medium roots; moderately acid; clear wavy boundary. (4 to 9 inches thick)

E1--7 to 17 inches; pale brown (10YR 6/3) fine sand; single grained; loose; common fine and medium roots; neutral; gradual wavy boundary.

E2--17 to 29 inches; very pale brown (10YR 7/3) fine sand; single grained; loose; few fine and medium roots; neutral; clear wavy boundary. (Combined thickness of the E horizon is 16 to 32 inches)

Bt--29 to 33 inches; brownish yellow (10YR 6/6) sandy clay loam; weak medium subangular blocky structure; friable; few fine and medium roots; sand grains are well coated and bridged with clay; neutral; abrupt wavy boundary. (3 to 20 inches thick)

2R--33 to 80 inches; white (10YR 8/2) limestone that can be dug with light power equipment such as a backhoe; moderately alkaline; the pedon had a 14 x 33 inch deep solution hole contained strong brown (7.5YR 5/6) sandy clay between depths of 52 to 60 inches; moderate medium subangular blocky structure; firm, few distinct clay films on peds; few fine limestone nodules and fragments; neutral.

TYPE LOCATION: Alachua County, Florida; about 200 feet east of Parker Road (S. W. 122nd Street) 3.6 miles south of junction with State Road 26, 1.5 miles east of intersection of State Road 241 at Jonesville, NW1/4SW1/4, sec 24, T. 10 S. R. 18 E.

RANGE IN CHARACTERISTICS: Depth to limestone in about 60 to 65 percent of the pedon is 26 to 40 inches and in about 30 to 35 percent depth is 40 to 59 inches. Within the pedon, in solution holes, the solum extends to depths below 60 inches. Limestone or chert boulders are on the surface and within the solum of many areas, comprising up to 3 percent of the surface area.

The A horizon has hue 10YR, value of 3 to 5, and chroma of 1 or 2. Reaction ranges from strongly acid to slightly acid. Texture is sand or fine sand.

The E horizon predominantly has hue 10YR, value of 5 to 8 and chroma of 6 or less; or hue 2.5Y, value of 5 to 7, and chroma of 2 to 6 but ranges to hue 7.5YR, value 5 to 7, chroma 4 to 8 in some pedons. Reaction ranges from strongly acid to slightly acid. Texture is sand or fine sand. Where present, light gray streaks of uncoated sand grains are due to sand stripping and are not indicative of wetness.

The Bt horizon has hue 10YR or 7.5YR, value of 4 to 6, and chroma of 4 to 8, without mottles with chroma of 3 or more. Texture is sandy loam, fine sandy loam, or sandy clay loam. Reaction ranges from slightly acid to moderately alkaline. In some pedons, the lower 3 to 6 inches of the Bt horizon contains about 3 to 10 percent of limestone fragments 2 to 10 inches in size. In solution holes, which comprise about 1 to 20 percent, the texture of the Bt horizon is usually sandy clay loam in the upper part and sandy clay loam or sandy clay in the lower part. Fine to medium nodules of soft limestone are usually in the Bt horizon in the solution holes, but normally make up less than 20 percent by volume.

Some pedons have a 2Cr horizon of soft limestone above the harder limestone. Where present, hue is 10YR, value 7 or 8, chroma 1 or 2. Hard limestone fragments and boulders occur randomly throughout the horizon and range from few to many.

The 2R horizon is white limestone soft enough to be dug with light power equipment. Solution holes about 4 to 12 inches in diameter and filled with sandy loam or sandy clay loam occur in the 2Cr or 2R horizon. Depth to the underlying limestone is highly variable within short distances.

COMPETING SERIES: This is the Hague series in the same family and the Chiefland series in a closely similar family. Hague soils lack limestone within depths of 80 inches. Chiefland soils are in a thermic family.

GEOGRAPHIC SETTING: Jonesville soils occur on nearly level to gently sloping ridges and gently undulating uplands of the hyperthermic region of Florida. A few small limestone rock outcrops and lime sinks occur in the landscape. The soil formed in sandy and loamy marine sediments overlying limestone. The mean annual precipitation is about 50 to 60 inches and the mean annual temperature is about 70 to 74 degrees F. Slopes are 0 to 5 percent.

GEOGRAPHICALLY ASSOCIATED SOILS: These are the competing Hague series and the Apopka, Arredondo, Candler, Kendrick, Paola, Pedro, and Tavares series. All the associated soils except Pedro soils lack limestone within depths of 80 inches. Pedro soils have limestone within depths of 20 inches. Apopka and Arredondo soils have A and E horizons 40 to 80 inches thick. Candler, Paola, and Tavares soils are sandy to depths of 80 inches or more. Kendrick soils have low base saturation. In addition, Candler soils have lamellae and Tavares soils are moderately well drained.

DRAINAGE AND PERMEABILITY: Well drained. Runoff is slow. Permeability is rapid in the A and E horizons and moderate to moderately slow in the Bt horizon. Available water capacity is low in the A and Bt horizons and very low in the E horizon. The water table is below a depth of 72 inches.

USE AND VEGETATION: Many areas are cleared and used for tame pasture and cultivated crops such as corn, peanuts, tobacco, watermelons, and vegetables. Natural vegetation consists of slash and longleaf pines; post, bluejack, laurel and live oaks; scattered red oak and hickory. The understory is chalky and other bluestems, panicum, huckleberry, blackberry, pineland threeawn and scattered sawpalmetto.

DISTRIBUTION AND EXTENT: The hyperthermic region of Florida. The series is of small known extent.

MLRA OFFICE RESPONSIBLE: Auburn, Alabama

SERIES ESTABLISHED: Alachua County, Florida; 1947.

REMARKS: Diagnostic horizons and features in this pedon:

Ochric epipedon and arenic feature - 0 to 29 inches (A, E1, E2)

Argillic horizon - 29 to 33 inches (Bt)

Otela

LOCATION OTELA FL
Established Series
Rev. GRB
11/1999
OTELA SERIES
The Otela series consists of very deep, moderately well drained, moderately slowly to slowly permeable soils on broad uplands. They formed in sandy and loamy marine sediments over limestone on karst topography. Near the type location, the mean annual temperature is 68 degrees and the mean annual precipitation is 55 inches. Slopes range from 0 to 8 percent.

TAXONOMIC CLASS: Loamy, siliceous, semiactive, thermic Grossarenic Paleudalfs

TYPICAL PEDON: Otela fine sand - on a 1 percent slope of planted pines. (Colors are for moist soils.)

Ap--0 to 8 inches; dark grayish (10YR 4/2) fine sand; weak fine granular structure; very friable; strongly acid; abrupt smooth boundary. (1 to 10 inches thick).

E1--8 to 21 inches; brown (10YR 5/3) fine sand; single grained; loose; common root channels, 1 to 5 cm in diameter; strongly acid; clear wavy boundary.

E2--21 to 32 inches; very pale brown (10YR 8/3) fine sand; single grained; loose; common root channels about 1 to 5 cm in diameter; common medium distinct white (10YR 8/1) pockets of uncoated sand grains and common medium distinct yellow (10YR 7/6) masses of iron accumulation; strongly acid; gradual smooth boundary.

E3--32 to 50 inches; white (10YR 8/1) fine sand; single grained; loose; few brownish yellow (10YR 6/6) lamellae about 4 mm thick with texture of loamy fine sand; common fine distinct brownish yellow (10YR 6/6) masses of iron accumulation; very strongly acid; abrupt smooth boundary. (Combined thickness of the A and E horizons is 40 ranges from 78 inches.)

Bt1--50 to 61 inches; brownish yellow (10YR 6/6) fine sandy loam; moderate fine subangular blocky structure; friable; clean sand grains on faces of peds; extremely acid; clear smooth boundary.

Bt2--61 to 68 inches; brownish yellow (10YR 6/6) sandy clay loam; moderate fine subangular blocky structure; friable; common fine distinct reddish yellow (7.5YR 6/6) masses of iron accumulation; common medium distinct light gray (10YR 7/2) areas of iron depletions; very strongly acid; clear smooth boundary. (Combined thickness of the Bt horizons range from 2 to 40 inches.)

Btg-68 to 80 inches; light gray (10YR 7/2) sandy clay loam; weak coarse subangular blocky structure; friable; common fine distinct brownish yellow (10YR 6/6) masses of iron accumulation; common fine faint light gray (10YR 7/1) areas of iron depletions; extremely acid.

TYPE LOCATION: Levy County, Florida. Approximately 2 miles northeast of Chiefland, about 75 feet north and about 2,200 feet east of the southwest corner of sec. 20, T 11 S., R 15 E.

RANGE IN CHARACTERISTICS: Solum thickness and depth to limestone bedrock ranges from 60 to more than 80 inches. Soil reaction ranges from very strongly acid to neutral in the A and E horizons, and from extremely acid to slightly alkaline in the upper Bt horizons and from extremely acid to moderately alkaline in the lower Bt horizons.

The A or Ap horizon has hue of 10YR, value of 3 to 6, and chroma of 1 to 3. Texture is sand or fine sand.

The E horizon has hue of 10YR, value of 5 to 7, and chroma of 2 to 8; or value of 8, and chroma of 1 to 3. Redoximorphic features in shades of brown or yellow range from none to common. Texture is sand or fine sand. Some pedons have many pockets of white uncoated sand grains. Thin lamellae having texture of loamy fine sand or sandy loam are present in most pedons. Pebble-sized ironstone nodules, less than about 5 percent by volume, occur in the lower parts of the E horizon in some pedons. Pebble to cobble-sized limestone or chert fragments, less than about 5 percent by volume, may be present in the E and EB horizons in some pedons.

The EB horizon, where present, has colors similar to the Bt horizon. Texture is loamy fine sand.

The Bt horizon has hue of 10YR, value of 5 to 8, and chroma of 3 to 8. Redoximorphic features in shades of gray, brown, red, or yellow range from few to many. Texture is sandy loam, fine sandy loam, or sandy clay loam. The weighted average clay content is 15 to 35 percent in the upper 20 inches of the Bt horizon. In some pedons, less than about 5 percent, by volume, pebble to stone-sized limestone or chert fragments may be present.

The Btg horizon, where present, has hue of 10YR to 5Y, value of 5 to 7, and chroma of 1 or 2; or it is neutral with value of 5 to 7. Redoximorphic features in shades of gray, yellow, brown, or red range from none to many. Texture is sandy loam, fine sandy loam, sandy clay loam, or sandy clay. Some pedons have a 2Btg horizon that has texture of sandy clay or clay. In some pedons, about 5 percent, by volume, pebble or cobble-sized limestone or chert fragments may be present in the lower part.

The BC horizon, where present at depths greater than 60 inches, has hue of 10YR, value of 3 or 6, and chroma of 6 or 8. Texture is fine sand or loamy fine sand.

COMPETING SERIES: The Lutterloh series is in the same family. The somewhat poorly drained Lutterloh soils have a water table at a depth of 20 to 30 inches for 2 to 4 months during the year.

GEOGRAPHIC SETTING: Otela soils are on broad uplands. They formed in unconsolidated sand and loamy marine sediments on karst topography. Slopes range from 0 to 8 percent. The average annual temperature ranges from 65 to 70 degrees F., and the average annual precipitation ranges from 50 to 60 inches.

GEOGRAPHICALLY ASSOCIATED SOILS: These include the Orsino, Penney, Shadeville, and Tavares soils. The Orsino, Penney, and Tavares soils are sandy to depths of 80 inches, or more. In addition, Penney soils are excessively well drained. Shadeville soils are deep to limestone bedrock.

DRAINAGE AND PERMEABILITY: Moderately well drained; moderately rapid to rapid permeability in the A and E horizons and moderately slow to slow permeability in the Bt and Btg horizons.

USE AND VEGETATION: Most areas of Otela soils are used for improved pasture, cultivated crops or planted pines. Peanuts, sorghum, and watermelon are the principal crops grown on this soil. The natural vegetation consists of laurel oak, live oak, turkey oak, slash pine, longleaf pine, as well as scattered hickory and red oak. The understory includes such plants as pineland threeawn, lopsided indiangrass, and creeping bluestem.

DISTRIBUTION AND EXTENT: The North Central Florida Ridge and Gulf Coast Uplands. The series is of moderate extent.

MLRA OFFICE RESPONSIBLE: Auburn, Alabama.

SERIES ESTABLISHED: Wakulla County, Florida, 1988.

REMARKS: Diagnostic horizons and features recognized in this pedon are:

Ochric epipedon - The zone from the soil surface to a depth of approximately 50 inches (A and E horizons).

Argillic horizon - The zone from about 50 to 80 inches (Bt1, Bt2, and Btg horizons).

A water table is perched above the Bt horizon for about 1 to 4 months, or for short duration during periodic high rainfall.

Seaboard

LOCATION SEABOARD FL
Established Series
Rev. GRB
07/1999
SEABOARD SERIES
The Seaboard series consists of shallow, moderately well drained, rapidly permeability soils on broad, low uplands of the Lower Coastal Plain. They formed in sandy marine or eolian sediments over fractured porous limestone bedrock. Near the type location, the mean annual temperature is about 68 degrees F., and the mean annual precipitation is about 55 inches. Slopes range from 0 to 3 percent.

TAXONOMIC CLASS: Thermic, uncoated Lithic Quartzipsamments

TYPICAL PEDON: Seaboard fine sand - on a 1 percent slope of forested low uplands. (Colors are for moist conditions.)

A--0 to 6 inches; light brownish gray (10YR 6/2) fine sand; single grained; loose; strongly acid; clear smooth boundary. (3 to 9 inches thick)

C--6 to 14 inches; light gray (10YR 7/2) fine sand; many coarse white (10YR 8/1) streaks and pockets of clean sands; single grained; loose; slightly acid; abrupt irregular boundary. (0 to 15 inches thick)

2R--14 inches; fractured porous limestone bedrock.

TYPE LOCATION: Wakulla County, Florida. Approximately 20 feet west of major powerline; about 1,200 feet south of State Road 365, and about 0.5 miles southwest of Wakulla; NW 1/4, NE 1/4. Sec. 16, T. 3 S., R. 1 E.

RANGE IN CHARACTERISTICS: Depth to limestone ranges from 10 to 20 inches. Soil reaction ranges from strongly acid to moderately acid in the surface and moderately acid to neutral in the underlying horizon. Many pedons have up to 5 percent, by volume, pebble to boulder-size limestone or chert fragments at the soil surface, or within the soil.

The A horizon has hue of 10YR, value of 4 to 7, and chroma of 1 to 3. Texture is sand or fine sand.

The C horizon has hue of 10YR, value of 5 to 8, and chroma of 2 to 6. Masses of iron accumulation range in shades of brown or yellow range from none to common. Most pedons have few to common, fine to coarse pockets of white or light gray sand grains, with chroma of 2. The chroma of 2 is due to uncoated sand grains and does not indicate wetness. Texture is sand or fine sand.

The Cr horizon, where present, has hue of 10YR or 2.5Y, value of 6 or 8, and chroma of 1 to 4. It is composed of soft, weathered, fractured limestone that can be dug with difficulty with a spade, has very firm to extremely firm rupture resistance with low to high excavation difficulty. It usually contains soft carbonate accumulations along with few to many hard limestone or chert fragments. It is highly irregular and interspersed with solution holes that range from 4 to 12 inches in diameter and filled with sandy loam to sandy clay textured soil material. Depth to limestone is variable within short distances.

The 2R horizon is composed of hard, unweathered limestone that has slightly rigid to very rigid rupture resistance with very high to extremely excavation difficulty. Some areas contain solution holes filled with Btg and/or Cr material.

COMPETING SERIES: There are no other known series in this family.

GEOGRAPHIC SETTING: Seaboard soils are on low uplands. They formed in sandy marine or eolian sediments overlying porous limestone bedrock. Slopes range from 0 to 3 percent. The average annual temperature ranges from 66 to 70 degrees F., and the average annual rainfall ranges from 50 to 60 inches.

GEOGRAPHICALLY ASSOCIATED SOILS: These include the Moriah, Ortega, Otela, Ridgewood and Shadeville soils. The somewhat poorly drained Moriah soils have an argillic horizon and are deep to limestone bedrock. Ortega, Otela, and Ridgewood soils are very deep. In addition, Otela soils have argillic horizons and Ridgewood soils are somewhat poorly drained. Shadeville soils are deep to limestone and have argillic horizons.

DRAINAGE AND PERMEABILITY: Moderately well drained; rapid permeability.

USE AND VEGETATION: Most areas of Seaboard soils are forested. Natural vegetation consists of slash pine, laurel oak, live oak, hickory, persimmon, and dogwood. The understory consists of native grasses and shrubs including pineland threeawn and greenbrier.

DISTRIBUTION AND EXTENT: These soils are of minor extent on the Lower Coastal Plain.

MLRA OFFICE RESPONSIBLE: Auburn, Alabama.

SERIES ESTABLISHED: Wakulla County, Florida, 1988.

REMARKS: Diagnostic horizons and features recognized in this pedon are:

Ochric epipedon - The zone from the surface to a depth of about 6 inches (A horizon).

Lithic Contact - at a depth of 14 inches (2R horizon).

A seasonal high water table below depths of 48 inches occurs within the fractured porous limestone bedrock.

Chobee

LOCATION CHOBEE FL
Established Series
Rev. WGH:AGH
06/2001
CHOBEE SERIES
The Chobee series consists of deep, very poorly drained, slowly to very slowly permeable soils that formed in thick beds of loamy marine sediments. They occur mostly in small to large depressions and low, nearly level areas and occasionally on river flood plains in the lower Coastal Plain. Slopes range from 0 to 2 percent.

TAXONOMIC CLASS: Fine-loamy, siliceous, superactive, hyperthermic Typic Argiaquolls

TYPICAL PEDON: Chobee fine sandy loam--tame pasture.

(Colors are for moist soil.)

Ap--0 to 7 inches; black (10YR 2/1) fine sandy loam; moderate medium granular structure; friable; many fine and medium roots; few small gray sand pockets; many clean sand grains; slightly acid; clear smooth boundary. (4 to 19 inches thick)

Bt--7 to 22 inches; black (10YR 2/1) sandy clay loam; weak coarse subangular blocky structure; sticky and slightly plastic; common fine and medium roots; sand grains bridged with clay; few patchy clay films in root channels; common gray sand streaks and pockets; mildly alkaline; gradual wavy boundary. (4 to 30 inches thick)

Btkg1--22 to 28 inches; very dark gray (10YR 3/1) sandy clay loam; weak coarse subangular blocky structure; sticky and plastic; few fine roots; many fine to coarse, soft to semi-hard white nodules of carbonate; moderately alkaline; calcareous; gradual wavy boundary. (8 to 18 inches thick)

Btkg2--28 to 63 inches; dark gray (10YR 4/1) sandy clay loam; many coarse faint pockets of very dark gray and few fine distinct yellowish brown and strong brown mottles; weak, coarse subangular blocky structure; sticky and plastic; many medium streaks and pockets of grayish brown (10YR 5/2) fine sand; many fine and medium nodules of carbonate; moderately alkaline; calcareous; gradual irregular boundary. (12 to 28 inches thick)

Cg--63 to 75 inches; gray (10YR 5/1) loamy fine sand; many fine to coarse, faint dark grayish brown (10YR 4/2) mottles; massive; slightly sticky; many pockets of gray (N 5/0) and white (N 8/0) fine sand and many fine and medium pockets of very dark gray (10YR 3/1) sandy clay loam; few small white (N 8/0) nodules of carbonate; moderately alkaline; calcareous.

TYPE LOCATION: Okeechobee County, Florida, about 6 1/2 miles northeast of the center of Okeechobee on Williamson's Ranch. SE1/4NW1/4 sec. 24, T. 36 S., R. 35 E.

RANGE IN CHARACTERISTICS: Solum thickness and depth to limestone is more than 40 inches.

The A horizon has hue of 10YR, value of 2 or 3, and chroma of 1 or 2; or hue of N, value of 2 or 3. Texture is loamy sand, loamy fine sand, sandy loam, or fine sandy loam. Reaction is moderately acid to neutral. In depressional and flood plain areas, some pedons have thin muck surfaces.

The Bt horizon has hue of 5GY to 10YR, value of 2 to 7, and chroma of 1 to 2; or hue of N, value of 2 or 3. Texture of the Bt horizon is fine sandy loam or sandy clay loam. Weighted clay content of the control section ranges from 18 to 35 percent. Reaction ranges from slightly acid to moderately alkaline in the upper part and from neutral to moderately alkaline and calcareous in the lower part. A few shell fragments are in the lower part in some pedons. In some pedons the Bt horizon contains small bodies of pyrite but this cannot be predicted without testing. Lowering the water table can result in the pyrite reacting to form acids that may lower the pH in local spots within the horizon to 3.5 or less.

The C horizon has hue of 2.5Y to 10YR, value of 4 to 7, and chroma of 1 to 4; or hue of 5GY, value of 5 or 6, and chroma of 1. Texture is loamy sand, loamy fine sand, fine sandy loam, or sandy loam. In some pedons, this horizon is a mixture of sand and shell fragments.

COMPETING SERIES: Copeland and Manatee series are in closely similar families. Copeland soils have sola less than 40 inches thick. Manatee soils are in a coarse-loamy family.

GEOGRAPHIC SETTING: Chobee soils are mostly in small to large depressions or low, nearly level areas and occasionally on river flood plains. Gradients are less than 2 percent. They formed in thick beds of moderately fine textured materials. Rainfall averages about 50 to 60 inches annually and mean annual air temperature is about 70 to 74 degrees F.

GEOGRAPHICALLY ASSOCIATED SOILS: These are the competing Copeland and Manatee series and Bradenton, Felda, Riviera, Wabasso, and Winder series. Bradenton, Felda, and Riviera soils are slightly better drained. Riveria and Winder soils have tongues of E horizon in the Bt horizon. Wabasso soils have a Bh horizon over Bt horizons.

DRAINAGE AND PERMEABILITY: Chobee soils are very poorly drained. Runoff and internal drainage are slow. Permeability is slow to very slow. The water table is within 6 inches for 1 to 4 months during most years. Depressional areas are ponded for long duration in most areas.

USE AND VEGETATION: Drained areas are used principally for tame pasture and range. Most of the soils remain in their natural state and have vegetation consisting of pickerelweed, lilies, sawgrass, and scattered swamp maples in treeless areas. Some areas have a growth of ash, gum, maple, and cypress.

DISTRIBUTION AND EXTENT: Mainly in Peninsular Florida. The soil is of moderate extent.

MLRA OFFICE RESPONSIBLE: Auburn, Alabama

SERIES ESTABLISHED: Okeechobee County, Florida; 1970.

REMARKS: This soil was formerly included in the Manatee series.

Diagnostic horizons and features in this pedon:

Mollic epipedon - 0 to 28 inches (Ap, Bt1, Bt2)
Argillic horizon - 7 to 63 inches (Bt1, Bt2, Btg)

Gator

LOCATION GATOR FL
Established Series
Rev. AGH
03/2000
GATOR SERIES
The Gator series consists of very poorly drained organic soils that formed in moderately thick beds of hydrophytic plant remains overlying beds of loamy and sandy marine sediments. They are in depressions and on flood plains. Slopes are less than 1 percent.

TAXONOMIC CLASS: Loamy, siliceous, euic, hyperthermic Terric Haplosaprists

TYPICAL PEDON: Gator muck on a 0 percent slope in a marsh. (Colors are for moist soil.)

Oa--0 to 34 inches; black (5YR 2/1) muck; about 10 percent fiber, less than 5 percent rubbed; moderate medium granular structure; friable many fine roots; slightly acid in 0.01M calcium chloride; gradual wavy boundary. (16 to 50 inches thick)

Cg1--34 to 46 inches; very dark gray (10YR 3/1) sandy clay loam; massive; slightly sticky and plastic; slightly acid; gradual wavy boundary. (12 to 35 inches thick)

Cg2--46 to 52 inches; dark grayish brown (10YR 4/2) stratified loamy fine sand, fine sandy loam and fine sand; massive; nonsticky, nonplastic, slightly acid; gradual wavy boundary. (12 to 24 inches thick)

Cg3--52 to 58 inches; light gray (10YR 7/2) fine sand; single grained; loose; slightly acid.

TYPE LOCATION: Volusia County, Florida; about 4 miles west of DeLeon Springs in Lake Woodruff National Wildlife Refuge, about 1.5 miles east of Lake Woodruff and 0.5 mile southwest of Spring Garden Lake in cordgrass marsh.

RANGE IN CHARACTERISTICS: The pH is 4.5 or more in 0.01 M calcium chloride in at least some part of the organic materials in the control section. Some parts can be as acid as pH 3.6. The pH is 6.1 to 7.8 by the Hellige-Troug method in the Oa horizon. The reaction is very strongly acid to moderately alkaline in the Cg1 horizon, and strongly acid to moderately alkaline in the underlying horizons.

Thickness of the organic material ranges from 16 to 50 inches. Depth to loamy material is less than 51 inches. The Oa horizon has hue of 10YR to 5YR, value of 2 or 3, and chroma of 2 or less. Sodium pyrophosphate extract colors have hue of 10YR, value of 2 to 4, chroma of 4 or less, or value of 5, and chroma or 2 to 4, or value of 6 chroma of 3 or 4. Electrical conductivity in areas of saline seeps is more than 16.

The Cg1 and Cg2 horizons have hue of 10YR to 5Y, value of 2 to 7, and chroma of 2 or less. Texture is sandy clay loam, loam, sandy loam or fine sandy loam. Thin strata of sandy clay may be present. Organic matter content is less than 20 percent. In some pedons there is sand, fine sand, loamy sand, or loamy fine sand 4 to 15 inches thick immediately below the Oa horizon. Where present, it is underlain by a layer of sandy clay loam sufficiently thick to qualify for a loamy family. The Cg2 horizon commonly is stratified with loamy fine sand, fine sandy loam, or fine sand. Electrical conductivity may range from 0 to 8 in the upper part and from 2 to 4 in the lower part in areas of saline seeps.

The Cg3 horizon has hue of 10YR to 5GY, value of 4 to 7, and chroma of 2 or less. The texture is primarily fine sand, sand, or loamy sand, but may include strata of sandy loam and sandy clay loam. Electrical conductivity ranges from 0 to 4 in areas of saline seeps. Fragments of shell and/or soft masses of calcium carbonate may be present.

COMPETING SERIES: There are no other series in the same family. Closely related soils are the Kaliga, Okeelanta, Samsula, and Tomoka series. Okeelanta soils are sandy or sandy-skeletal. Samsula soils are sandy or sandy-skeletal and dysic. Kaliga and Tomoka soils are dysic.

GEOGRAPHIC SETTING: Gator soils are in depressions and on flood plains of lakes, rivers, and streams on the lower Coastal Plain in central and south Florida. Slopes are less than 1 percent. The mean annual precipitation is about 50 to 60 inches, and the mean annual air temperature is about 70 to 74 degrees F.

GEOGRAPHICALLY ASSOCIATED SOILS: These are the Holopaw, Riviera, Tequesta, and Terra Ceia series. Holopaw, Riviera, and Tequesta soils are mineral soils. Tequesta soils have a histic epipedon. Terra Ceia soils do not have mineral horizons within the control section.

DRAINAGE AND PERMEABILITY: Gator soils are very poorly drained. They are saturated with water that is always at or above the surface except during extended droughts. Flood plains are flooded for a very long duration. Permeability is rapid in the Oa and moderate in the loamy parts of the Cg horizon.

USE AND VEGETATION: Almost all areas are in marsh or swamp wetlands used for wildlife and water storage. Native vegetation is mostly cordgrass or Jamaica sawgrass, maidencane, Coastal Plain willow, redosier dogwood, or swamp vegetation including baldcypress, sweetgum, red maple, and American hornbeam.

DISTRIBUTION AND EXTENT: Central and southern portions of Peninsular Florida. The series is of moderate extent.

MLRA OFFICE RESPONSIBLE: Auburn, Alabama

SERIES ESTABLISHED: Volusia County, Florida; 1977.

REMARKS: Gator soils have been included in the Tomoka soils in adjacent surveys.

Diagnostic features recognized in this pedon are:

Histic epipedon--the zone from the surface to a depth of 16 inches.

Surface tier--the zone from the surface to a depth of 12 inches.

The subsurface tier--the zone between 12 and 34 inches.

DATA: Soil Characterization Lab., IFAS, UOF
S8-9-(1-10), S31-12-(1-8), S18-7-(1-7), S31-16-(1-8),
S43-15-(1-4)

Pineda

LOCATION PINEDA FL
Established Series
Rev. TEC:AGH
01/98
PINEDA SERIES
The Pineda series consists of deep and very deep, poorly to very poorly drained, slowly to very slowly permeable soils that formed in thick beds of marine sandy and loamy sediments on the lower Coastal Plain. Slopes range from 0 to 2 percent.

TAXONOMIC CLASS: Loamy, siliceous, active, hyperthermic Arenic Glossaqualfs

TYPICAL PEDON: Pineda sand--range. (Colors are for moist soil.)

A--0 to 1 inch; black (10YR 2/1) fine sand; single grained; loose; many fine and medium and few coarse roots; moderately acid; clear smooth boundary. (1 to 15 inches thick)

E--1 to 5 inches; very pale brown (10YR 7/3) fine sand; single grained; loose; many fine and medium roots; moderately acid; clear wavy boundary. (0 to 22 inches thick)

Bw1--5 to 13 inches; brownish yellow (10YR 6/8) fine sand; single grained; loose; strongly acid; clear wavy boundary.

Bw2--13 to 23 inches; strong brown (7.5YR 6/8) fine sand; single grained; loose; moderately acid; clear wavy boundary. (Combined thickness of the Bw horizon is 6 to 30 inches thick)

E'--29 to 36 inches; light gray (10YR 7/2) fine sand; few fine distinct brownish yellow (10YR 6/6) mottles; single grained; loose; moderately acid; abrupt irregular boundary. (0 to 15 inches thick)

B/E--36 to 54 inches; light brownish gray (2.5Y 6/2) fine sandy loam (Btg) with 20 percent light gray (10YR 7/2) vertical tongues or intrusions of fine sand (E) 3 to 10 inches in length and 1/2 inch to 2 inches in width; weak fine subangular blocky structure; slightly sticky and slightly plastic; sandy intrusions are single grained and loose; neutral; abrupt irregular boundary. (2 to 40 inches thick)

Cg--54 to 80 inches; light gray (10YR 7/1) fine sand; single grained; loose; slightly acid.

TYPE LOCATION: Lee County, Florida; about 2,900 feet north of the intersection of Shands and Baker-Alico Road rock pit and the Florida Power and Light powerline, and 100 feet west of the powerline. NW1/4NW1/4SW1/4, sec. 6, T. 46 S., R. 26 E.

RANGE IN CHARACTERISTICS: Solum thickness is 40 to 80 inches. Combined thickness of the A, E, E', and Bw horizons is 20 to 40 inches. Soil reaction ranges from very strongly acid to neutral in the A, E, E', and Bw horizons, strongly acid to moderately alkaline in the Btg horizon, and moderately acid to moderately alkaline in the Cg horizon.

The A horizon has hue of 10YR, value of 2 to 5, and chroma of 1 or 2; or it is neutral, value of 2 to 4; where the value is 3.5 or less, thickness is less than 10 inches. Texture is sand or fine sand.

The E horizon, where present, has hue of 10YR, 2.5Y or it is neutral, value of 4 to 8, and chroma of 1 to 3 with or without mottles in shades of gray, brown, or yellow. Texture is sand or fine sand.

The Bw horizon has hue of 10YR or 7.5YR, value of 4 to 8, and chroma of 3 to 8. Texture is sand or fine sand.

The E' horizon and E' part of the B/E have hue of 10YR, value of 5 to 8, and chroma of 2 to 4. Texture is sand or fine sand. In some pedons there may be a 1 or 2 inch weakly expressed Bh horizon at the base of the E' horizon. Chromas of 3 and 4 are due to impurities in sand grains rather than coatings on sand grains.

The B/E horizon has vertical sandy intrusions or tongues greater than 5 cm in length of the overlying albic materials (E) extending into it. The tongues range from about 5 cm or more in length and width and occupy more than 15 percent of the B/E horizon. The Btg part of the B/E horizon has hue of 10YR to 5BG or it is neutral with value of 4 to 7, and chroma of 1 or 2, with mottles in shades of yellow or brown. It is sandy loam, fine sandy loam, or sandy clay loam. Clay content averages between 15 and 25 percent. Some pedons have a Btg horizon with colors and textures similar to that of the Btg part of the B/E horizon.

The BC horizon, where present, has color similar to the Btg and B/E horizon. Texture is sandy loam, fine sandy loam, or sandy clay loam.

The Cg horizon has hue of 10YR to 5GY or it is neutral with value of 5 to 8 and chroma of 1 or 2. Texture is sand, fine sand, loamy sand, sandy loam, or sandy clay loam. In some pedons it is sand mixed with shell fragments. Limestone bedrock may occur in some soils below a depth of 40 inches.

COMPETING SERIES: These are Riviera, and Tequesta series in the same family. Riviera soils do not have high chroma in their Bw horizons. Tequesta soils have histic epipedons.

GEOGRAPHIC SETTING: These soils occur in depressions, low hammocks, poorly defined drainageways broad low flats or in flood plain areas of the lower coastal plain. Slopes are less than 2 percent. The soil developed in beds of loamy and sandy marine sediments that may contain shell fragments in the lower part. Average annual precipitation is about 50 to 60 inches and the mean annual air temperature is about 70 to 74 degrees F.

GEOGRAPHICALLY ASSOCIATED SOILS: These are Anclote, Boca, EauGallie, Felda, Floridana, Hallandale, Holopaw, Immokalee, Malabar, Manatee, Myakka, Oldsmar, Parkwood, Pompano, Riviera, Wabasso, and Winder series. Anclote, Floridana, and Manatee soils have mollic epipedons. EauGallie, Immokalee, Myakka, Oldsmar, and Wabasso soils have spodic horizons. Boca and Hallandale soils have limestone. Holopaw and Malabar soils have Btg horizons 40 to 80 inches deep. Felda, Riviera and Winder soils lack Bw horizons. Winder soils have a sandy epipedon less than 20 inches thick. Parkwood soils have calcareous Bt horizons. Pompano soils are sandy to depths of 80 inches or more.

DRAINAGE AND PERMEABILITY: Pineda soils are poorly to very poorly drained; slow runoff; slow to very slow permeability. The water table is within depths of 12 inches for 1 to 6 months. In some areas the soil is flooded for about 7 days to 6 months. Depressions are ponded for periods of 3 to 6 months in most years.

USE AND VEGETATION: Citrus, truck crops, and tame pasture are grown on drained areas. In their undrained state, these soils are used for range. Natural vegetation is slash pine, cypress, myrtle, cabbage palm, blue maidencane, chalky bluestem, bluepoint panicum, sedges, pineland threeawn, and sand cordgrass.

DISTRIBUTION AND EXTENT: Peninsular Florida. The series is of moderate extent.

MLRA OFFICE RESPONSIBLE: Auburn, Alabama

SERIES ESTABLISHED: Brevard County, Florida; 1970.

REMARKS: Diagnostic horizons and features recognized in this pedon are:
Aquic moisture regime.

Arenic properties-- a sandy epipedon that is 36 inches thick. (A, E, Bw1, Bw2, E' horizons).

Albic horizons--the zones from 1 to 5 and 24 to 36 inches (E, E' horizons).

Argillic horizon--the zone from about 36 to 54 inches (B/E horizon).

Glossic horizon - zone form about 36 to 54 inches.

Holopaw

LOCATION HOLOPAW FL
Established Series
Rev. AGH
11/97
HOLOPAW SERIES
The Holopaw series consists of deep and very deep, poorly and very poorly drained soils formed in sandy marine sediments. These soils are rapidly permeable in the A and E horizons and moderately or moderately slowly permeable in the B horizon. These soils are on low lying flats, in poorly defined drainages or depressional areas. Slopes range from 0 to 2 percent.

TAXONOMIC CLASS: Loamy, siliceous, active, hyperthermic Grossarenic Endoaqualfs

TYPICAL PEDON: Holopaw sand--range. (Colors are for moist soil.)

A1--0 to 2 inches; very dark gray (10YR 3/1) sand; weak fine granular structure; very friable; many fine and medium roots; color is mixture of light gray sand grains and black organic matter; slightly acid; gradual smooth boundary. (2 to 7 inches thick)

A2--2 to 7 inches; dark gray (10YR 4/1) sand; weak fine granular structure; very friable; many fine roots; slightly acid; gradual smooth boundary. (0 to 14 inches thick)

Eg1--7 to 18 inches; grayish brown (10YR 5/2) sand; common medium distinct yellowish brown (10YR 5/6) mottles and many fine and medium faint gray to light gray (10YR 6/1) streaks; single grained; loose; common fine roots; slightly acid; gradual smooth boundary.

Eg2--18 to 35 inches; coarsely mottled gray (10YR 6/1) and grayish brown (10YR 5/2) sand; few fine faint very pale brown mottles and few medium distinct black streaks along root channels; single grained; loose; few fine roots; slightly acid; gradual smooth boundary.

Eg3--35 to 45 inches; gray (10YR 6/1) sand; single grained; loose; few fine roots; neutral; abrupt wavy boundary. (Combined thickness of the Eg horizon is 27 to 68 inches)

Btg--45 to 58 inches; gray (10YR 5/1) sandy loam; common fine faint light gray and common medium distinct dark yellowish brown (10YR 4/4) mottles; weak medium subangular blocky structure; friable; few fine roots; clay bridging between sand grains; mildly alkaline; gradual wavy boundary. (5 to 24 inches thick)

BCg--58 to 62 inches; gray (10YR 5/1) sandy loam; few medium distinct dark yellowish brown (10YR 4/4) mottles; massive; friable; common pockets and streaks of loamy sand and sandy clay loam; mildly alkaline; gradual wavy boundary. (0 to 8 inches thick)

Cg--62 to 71 inches; gray (5Y 5/1) loamy sand; massive; friable; common pockets and lenses of sand; mildly alkaline.

TYPE LOCATION: Brevard County, Florida. About 3 miles west of junction of Interstate Highway 95 and State Road 520; 3.5 miles north of State Road 520 on graded road and 30 feet west of intersection of graded roads in NW1/4NW1/4, sec. 9, T. 24 S., R. 35 E.

RANGE IN CHARACTERISTICS: Solum thickness ranges from 45 to 96 inches. Some pedons have a thin layer of muck on the surface. Soil reaction ranges from strongly acid to neutral in the surface layers and from strongly acid to moderately alkaline in the other layers. Limestone substratum phases are recognized.

The A horizon has hue of 10YR or 2.5Y, value of 2 to 4, and chroma of 2 or less. Where value is 3 or less, thickness is less than 7 inches. Texture is sand or fine sand.

The E horizon has hue of 10YR to 2.5Y, value of 4 to 7, and chroma of 3 or less. Texture is sand or fine sand.

The Btg horizon has hue of 10YR to 5GY, value of 4 to 7, and chroma of 2 or less with mottles. It is sandy loam, fine sandy loam, or sandy clay loam. Many pedons have pockets and lenses of sand. Clay content ranges from 13 to 28 percent with less than 20 percent silt. The BCg horizon has the same colors and mottles as the Btg horizon. Texture is sandy loam or fine sandy loam.

The Cg horizon has hue of 10YR to 5GY, value of 5 to 7, and chroma of 2 or less. Texture is sand, fine sand, loamy fine sand, or loamy sand. Fragments of shell are common in many pedons.

COMPETING SERIES: These are the Lokosee and Malabar series. Lokosee and Malabar soils have Bw horizons.

GEOGRAPHIC SETTING: Holopaw soils are on broad, low lying flats, poorly to well defined drainageways, or in depressional areas. Slopes are less than 2 percent. The soil formed in stratified unconsolidated marine sand and sandy loam. The climate is humid and warm. Precipitation is about 50 to 60 inches annually and mean annual air temperature is about 70 to 74 degrees F.

GEOGRAPHICALLY ASSOCIATED SOILS: These are the competing Lokosee and Malabar series; and the Bradenton, Ellzey, Felda, Floridana, Myakka, Panasoffkee, Pineda, Parkwood, Riviera, St. Johns, and Winder series. Myakka and St. Johns soils have a spodic horizon. The others have loamy material within 40 inches of the surface.

DRAINAGE AND PERMEABILITY: Holopaw soils are poorly and very poorly drained. Runoff is slow. Permeability is moderately slow. A water table is within 12 inches of the soil surface for 2 to 6 months during most years. Depressional areas are ponded for more than 6 months during most years

USE AND VEGETATION: Large areas of Holopaw soils are used for range. With adequate water control, these soils are used for citrus, truck crops, and tame pasture. Native vegetation is scattered slash and pond pine, cabbage and sawpalmettos, scattered cypress, myrtle, sand cordgrass, and pineland threeawn.

DISTRIBUTION AND EXTENT: Peninsular Florida. The series is of moderate extent.

MLRA OFFICE RESPONSIBLE: Auburn, Alabama

SERIES ESTABLISHED: Brevard County, Florida; 1970.

REMARKS: Diagnostic horizons and features in this pedon:

Ochric epipedon and grossarenic feature - 0 to 45 inches (A1, A2, Eg1, Eg2, Eg3)

Argillic horizon - 45 to 58 inches (Btg)

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Chapter 3
Well Installation and Additional Background Data

By Eberhard Roeder, Florida Department of Health, Bureau of Onsite Sewage Programs

Siting and Installation of Monitoring Wells

Siting

The location of wells was based on estimates about the groundwater flow directions. At Magnolia II, flow was presumed to move from the drainfield toward the Suwannee River. At this site, wells were installed in a fan pattern to capture a range of possible flow directions and dispersion along the plume. At Hickory, the groundwater flow directions were presumed to be directed towards the two sinks from a high point under the drainfields. The well pattern here allowed sampling into the direction of the two sinks, and within the area crossed by the drainfields. Figures 3-1 and 3-2 show the location of monitoring wells at the two sites and give an overview of the sites.

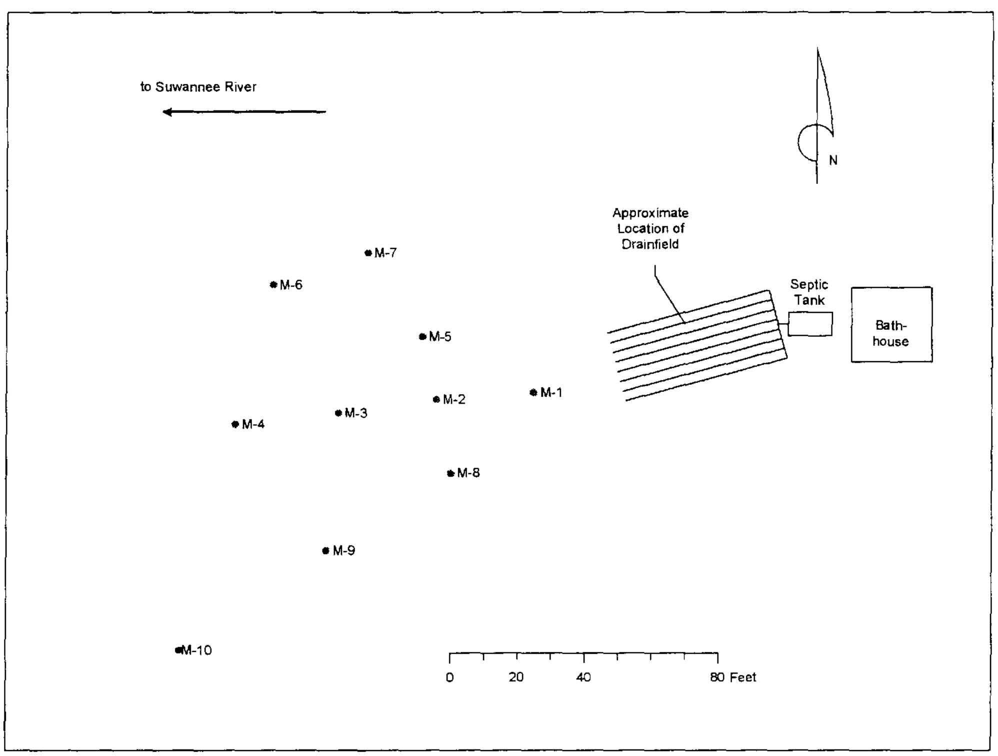

Figure 3- 1 Location of Monitoring Wells at Magnolia II Campground. Locations are based on survey by DOH staff.

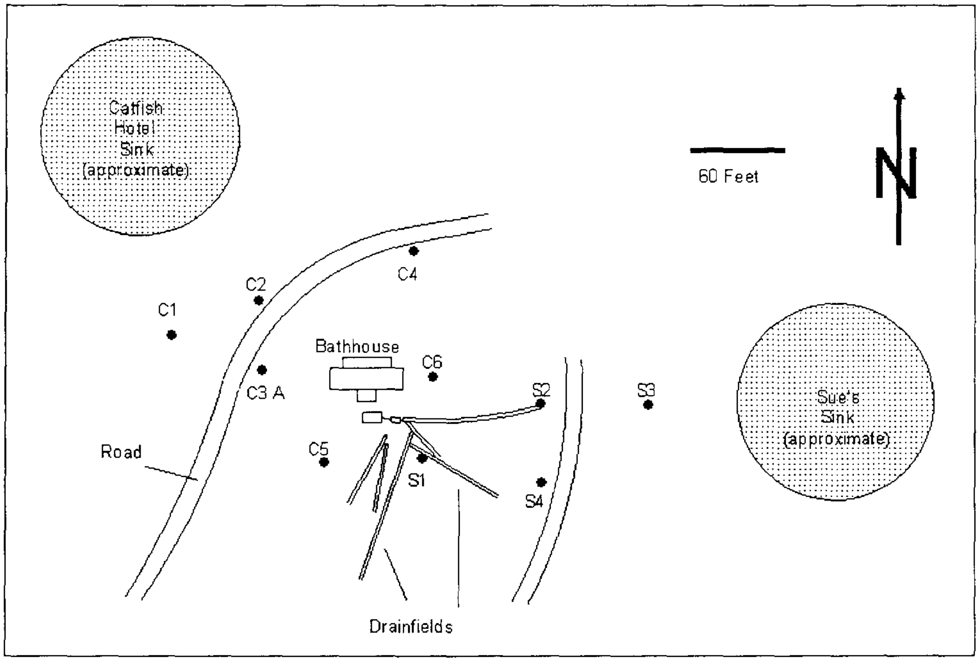

Figure 3- 2. Locations of Monitoring Wells at Hickory Campground. Locations are based on surveys by DOH staff.

Installation

During February, June, July, and August of 2002, Florida Geological Survey (FGS) staff under the direction of Ken Campbell installed ten wells at Magnolia II and ten wells at Hickory. One of the wells at Hickory, S1, was installed close to the intersection between two drainlines, where the GPR-survey had indicated a sinkhole or solution pipe. Florida Geological Survey staff drilled additional wells in February of 2003. Two wells were drilled on Camp Azalea Road south of the park and screened at different depths. A third background well, W18426 or AWM, was drilled north of the park in the Andrews Wildlife Management Area. The SRWMD also has wells in and around the park incorporated in their monitoring network. The wells installed by FGS and the SRWMD-wells close to the study site are shown on Figure 3-3.

Wells were installed using a drill. FGS used a truck-mounted mobile drill auger/core rig. A hollow stem auger wireline sampling system was utilized for sampling in the surficial sands and clays, and as temporary casing. The limestone was drilled using a diamond bit core barrel (3" O.D. bit; 1.875" diameter core). This was a "mud rotary" process in which drilling fluid (in this case clear water) was pumped down through the drill pipe and core barrel to cool the bit and carry cuttings back to the surface. In virtually all of the wells for this project, circulation was lost almost immediately after penetration into the limestone. The wells consisted of 2" diameter PVC pipe with a 10 foot slotted screen, with the exception of the AWM-well, which had a 20 foot screen. The top of the screen was located during drilling at a depth that appeared to be saturated and productive. In most cases the screens were close to the observed water table during installation, but at Magnolia II the screen depths were more variable than originally desired. For wells M-2, M-3 and M-10 the screens begin within five feet below the observed water table, for wells M-1, M-6, M-7, M-8 and M-9 the screens begin within five to 10 feet of the observed water table, and for well M-4 the screened interval was 19.3-29.3 feet below surface, about 15 feet below the observed water table after installation. One deep background well (CA-D) was screened between 25 and 35 feet below the surface.

The screened section was backfilled with silica sand; sealing of the wells was accomplished using bentonite. Bentonite grout was chosen over neat cement since it swells when placed in the annular space of the well. This provides an effective seal that is at least as good or better than cement grout in shallow water table situations (Klima et al. 1999), because bentonite is more flexible, less likely to shrink, and less costly (Wheaton et al. 1996).

Using handheld GPS units, Ken Campbell of FGS and Mark Hooks of DOH recorded approximate location of the wells during installation. Paul Booher of DOH surveyed the campground monitoring well locations created AutoCad LT drawings, which were later used to estimate local x-y coordinates. SRWMD provided more precise coordinates for the three wells outside of the park boundaries.

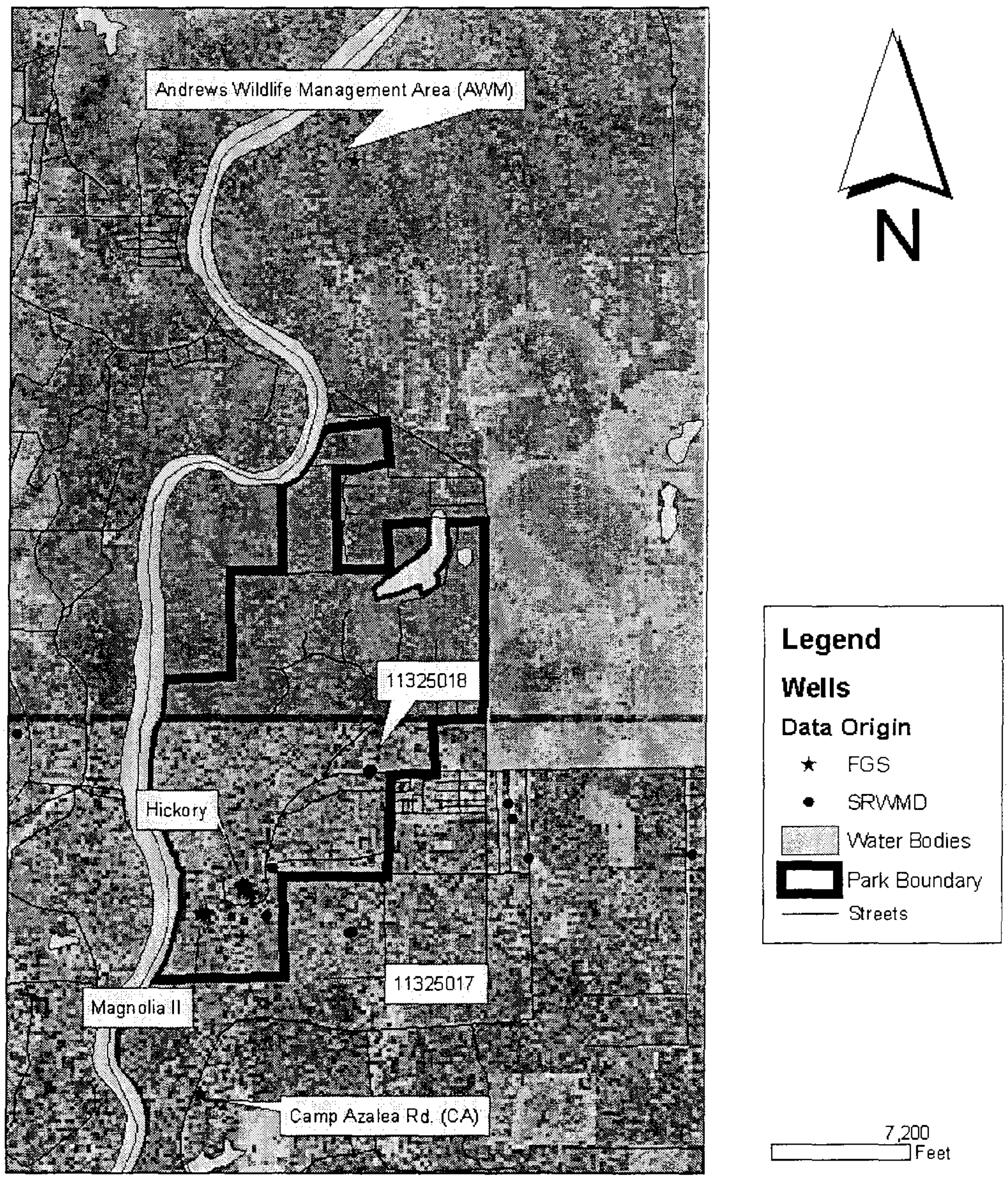

Figure 3- 3. Overview of locations of wells installed by FGS for this study and wells of the SRWMD in the vicinity of the two investigated OSTDS

Table 3- 1. Locations and Elevations of Wells Installed for this Study. Survey X and Y are relative to the origin of the respective AutoCad drawing.

Name	lat (degree)	long (degree)	Survey X (feet)	Survey Y (feet)	Elevation (feet NGVD 1929)
C-1	29.48832	82.97558	191.5	40.4	14.31
C-2	29.48812	82.97542	242.8	61.2	15.24
C-3A	29.48815	82.9757	243.6	17.9	15.88
C-4	29.48818	82.97522	337.0	92.3	16.11
C-5	29.48802	82.97555	283.7	-36.2	16.07
C-6	29.48798	82.97528	351.7	16.5	16.83
S-1	29.4879	82.97552	345.1	-35.6	16.33
S-2	29.48767	82.9749	419.4	-2.2	16.05
S-3	29.48768	82.97497	485.3	-2.2	14.26
S-4	29.48768	82.97525	417.5	-50.1	16.33
M-1	29.48627	82.97861	-8.6	119.7	10.27
M-2	29.48628	82.97861	-10.6	149.0	8.73
M-3	29.48632	82.97861	-14.8	178.2	8.12
M-4	29.48633	82.97889	-17.9	208.9	6.50
M-5	29.48637	82.97861	8.0	152.9	8.54
M-6	29.48627	82.97917	23.5	197.6	6.69
M-7	29.48637	82.97861	33.0	169.5	8.33
M-8	29.48623	82.97889	-32.8	144.4	8.52
M-9	29.48612	82.97861	-55.9	181.8	8.07
M-10	29.4862	82.97889	-86.1	225.4	6.69
CA-D	29.47334	82.97908	No survey	No survey	No survey
CA-S	29.47335	82.97912	No survey	No survey	No survey
AWM	29.53999	82.96612	No survey	No survey	No survey

During the spring of 2004, Paul Booher and Eberhard Roeder of DOH surveyed the elevations of the monitoring wells. Benchmarks were a permanent benchmark installed in 1958 at the Hickory site and a temporary benchmark at the Magnolia II site. During this survey the elevations of the gages in Manatee Springs and the Suwannee River were checked. The recorded Suwannee River gage readings were 0.35 feet too high. Table 3-1 provides location and elevation data for the installed wells.

Core Descriptions

During the well drilling, cores were collected continuously. The core was described subsequently using a modified Dunham classification, which is based on textures of carbonate rocks (http://www.sofia.usgs.gov/publications/ofr/03-68/images/app2/ modclass.gif, for additional references, see Neil and Cunningham 2003) and logged in the FGS Well Log Data System, which provides a computerized description framework. Printouts from the Well Log Data System are provided in appendix 3. The descriptions included an estimate for porosity obtained while examining the core samples under the microscope. For purposes of graphical representation, the description was simplified to include only the textural classification. During installation of the wells, the depth to water was recorded and included in the core description.

Figures 3-4 through 3-10 show simplified drawings of the core description. Only textural changes are shown, while color distinctions are not included. Limestone was encountered between one and 15 feet below ground surface. This is shallower than estimates in the GPR-study indicated. In close vicinity to the Hickory campground drainfields, the limestone was encountered at depths between one and three feet below ground surface. This suggests that the drainfields were partially located in the limestone instead of the sand. Also shown on these graphs are the water levels observed at the time of drilling, which gives an indication of the position of the water table.

The core descriptions show intermittent sand layers between limestone. There did not appear to be much continuity in sand bodies below the limestone or in the texture of limestone found at any given depth. This was even the case for cores immediately next to each other as in the case of CA-S and CA-D (Figure 3-9).

The existence of large-scale secondary porosity and permeability was indicated by references to cavity fill in the log descriptions and the loss of circulation upon encountering of rock (Campbell e-mail communication 2004). This was not apparent in the observations on small core samples.

Comparisons between GPR-results and core descriptions were hardly possible because the GPR-cross sections were not precisely georeferenced. Figure 3-11 compares the core description of well S1 with GPR-transect 14, which had been used to site S1. This comparison suggested that contacts between sand and limestone did not result in a strong contrast on the GPR-image. The core description confirmed the existence of cavities in the limestone, which in the case of S1 appeared to have been filled largely with sand and some unidentified material. In S1, as well as in C1, C5, and S3, sand was encountered below a layer of limestone.

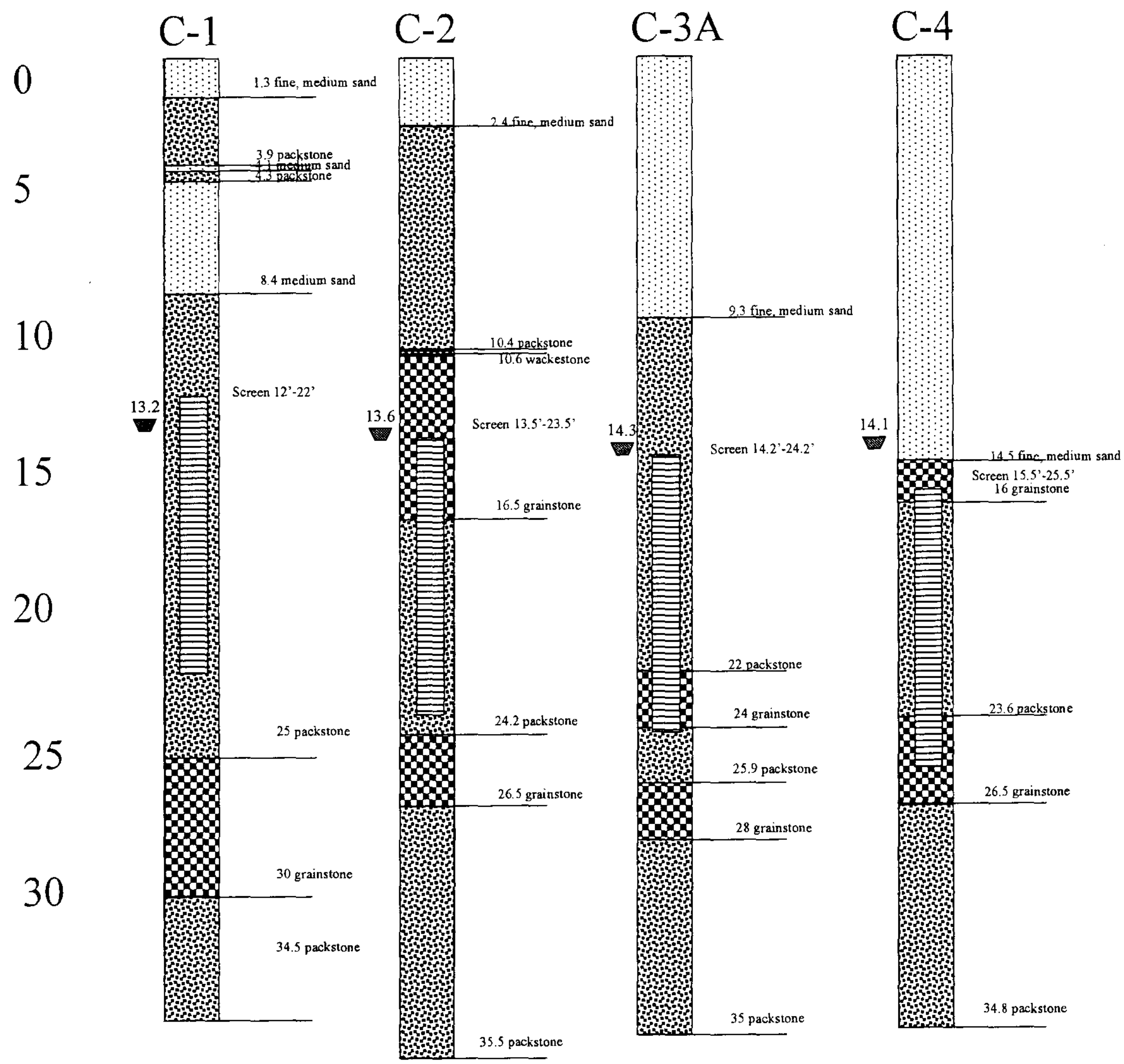

Figure 3- 4. Core descriptions of wells C-1, C-2, C-3A, and C-4. Trapezoid indicates depth to water.

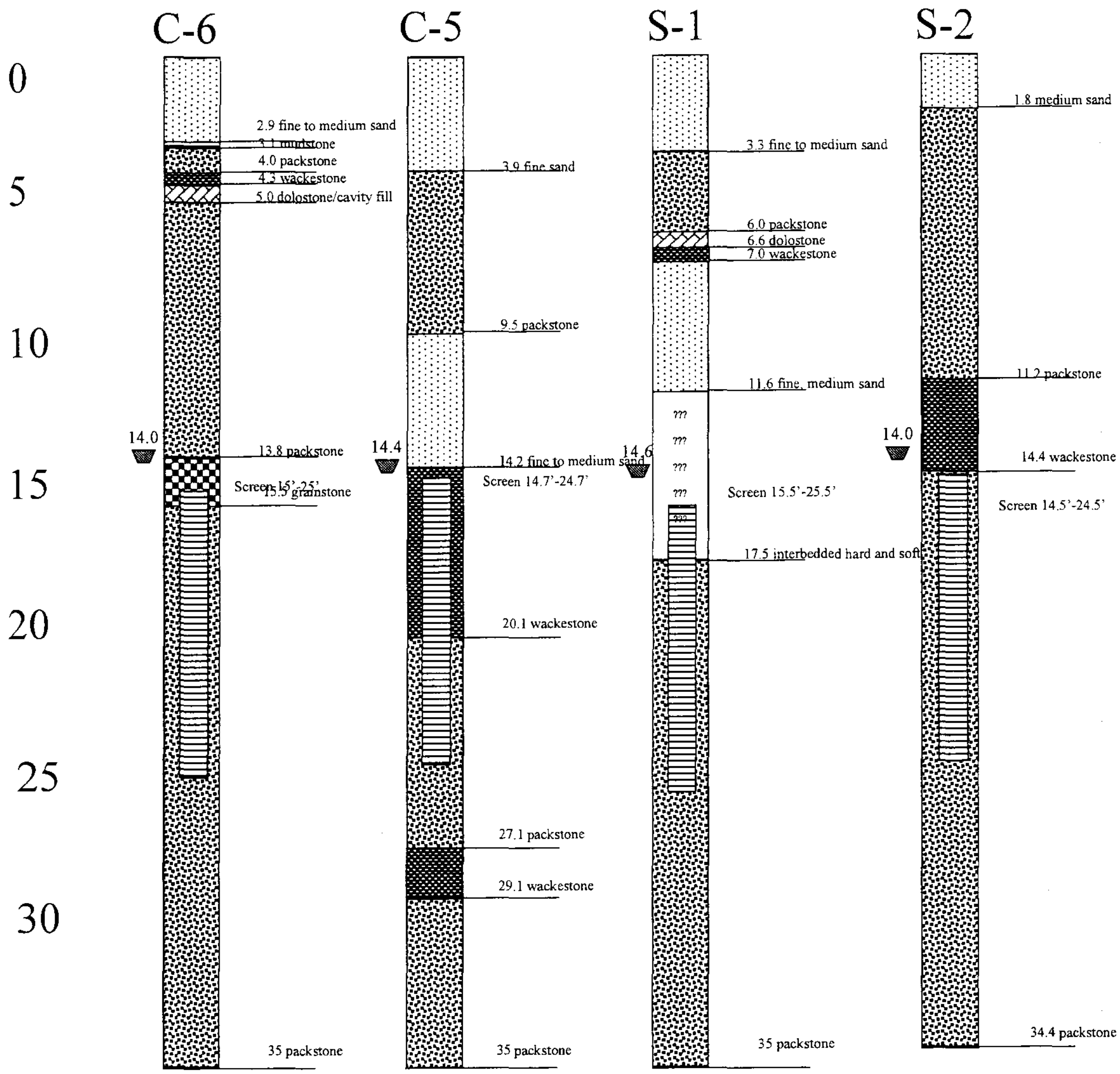

Figure 3- 5. Core descriptions of wells C-5, C-6, S-1, and S-2. Trapezoid indicates depth to water.

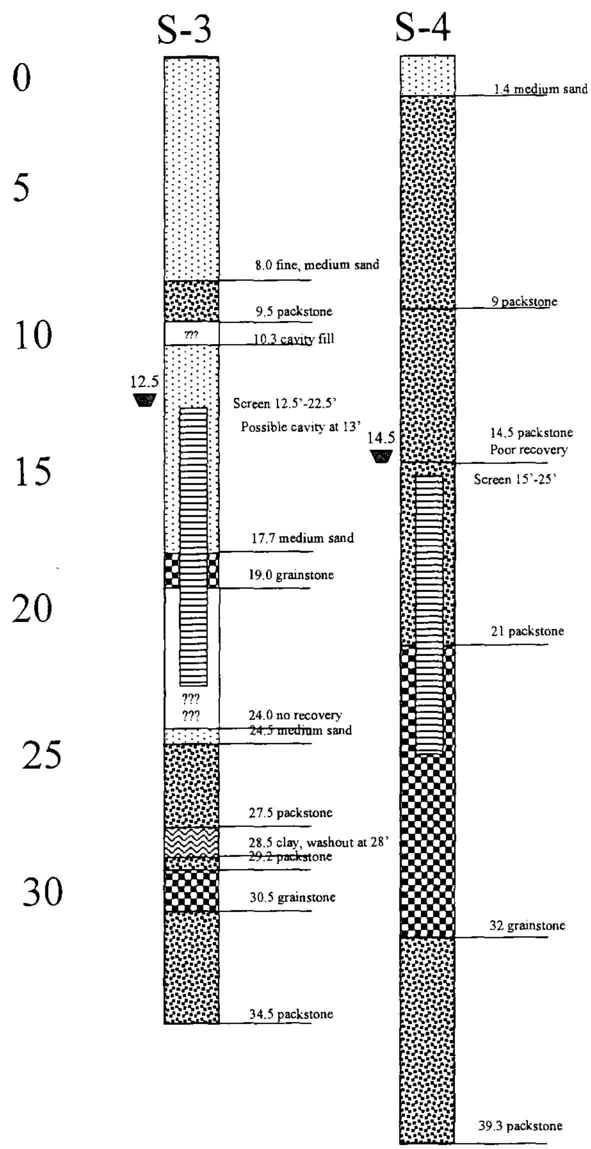

Figure 3- 6. Core descriptions of wells S-3 and S-4. Trapezoid indicates depth to water.

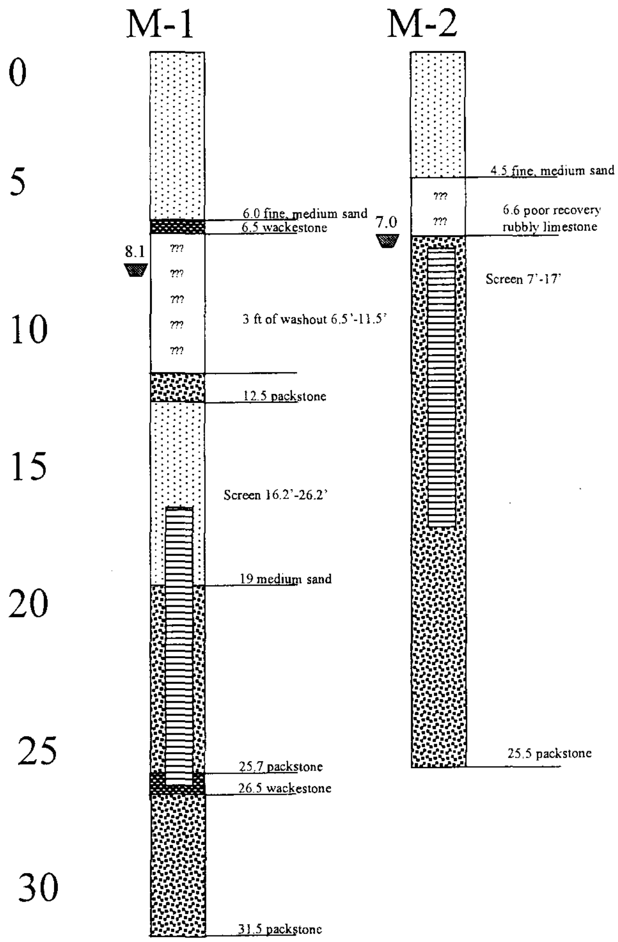

Figure 3- 7. Core descriptions of wells M-1 and M-2. Trapezoid indicates depth to water.

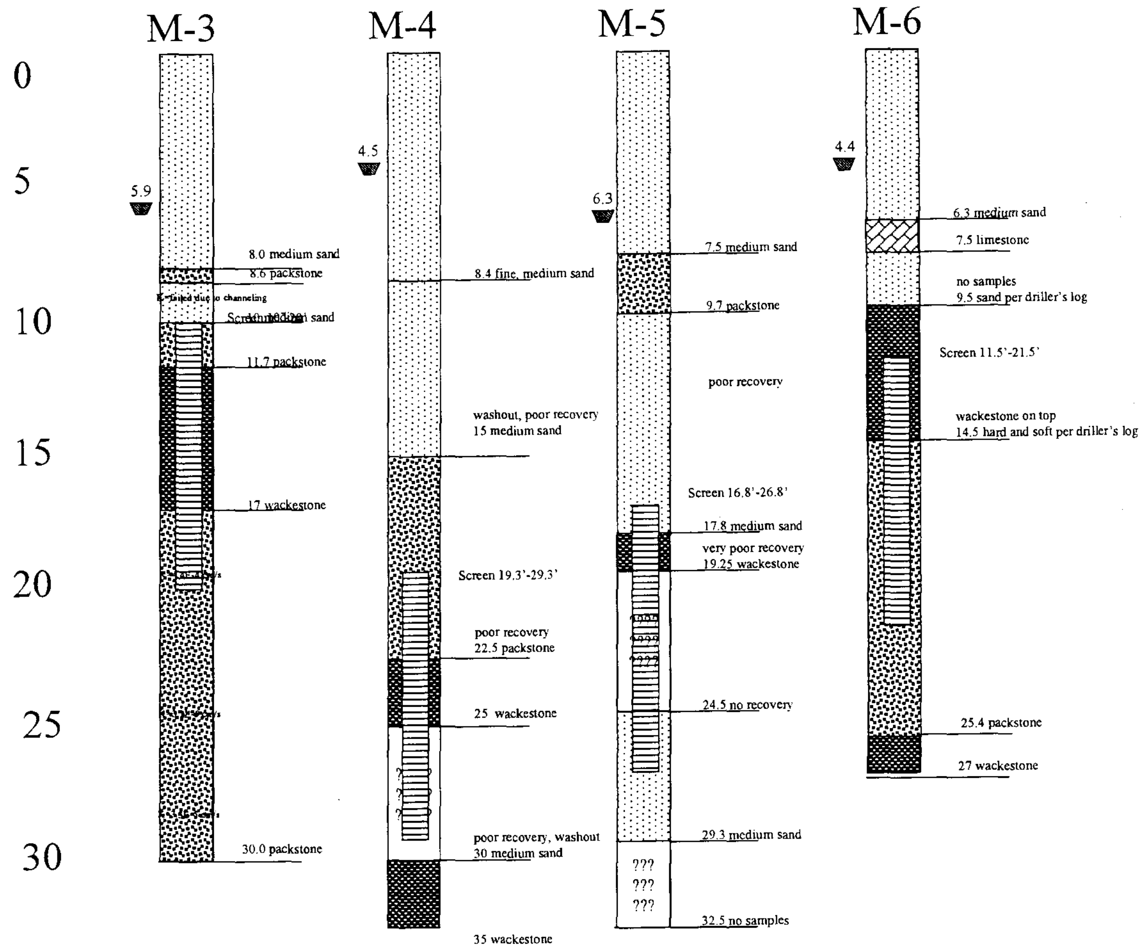

Figure 3- 8. Core descriptions of wells M-3, M-4, M-5, and M-6. Trapezoid indicates depth to water.

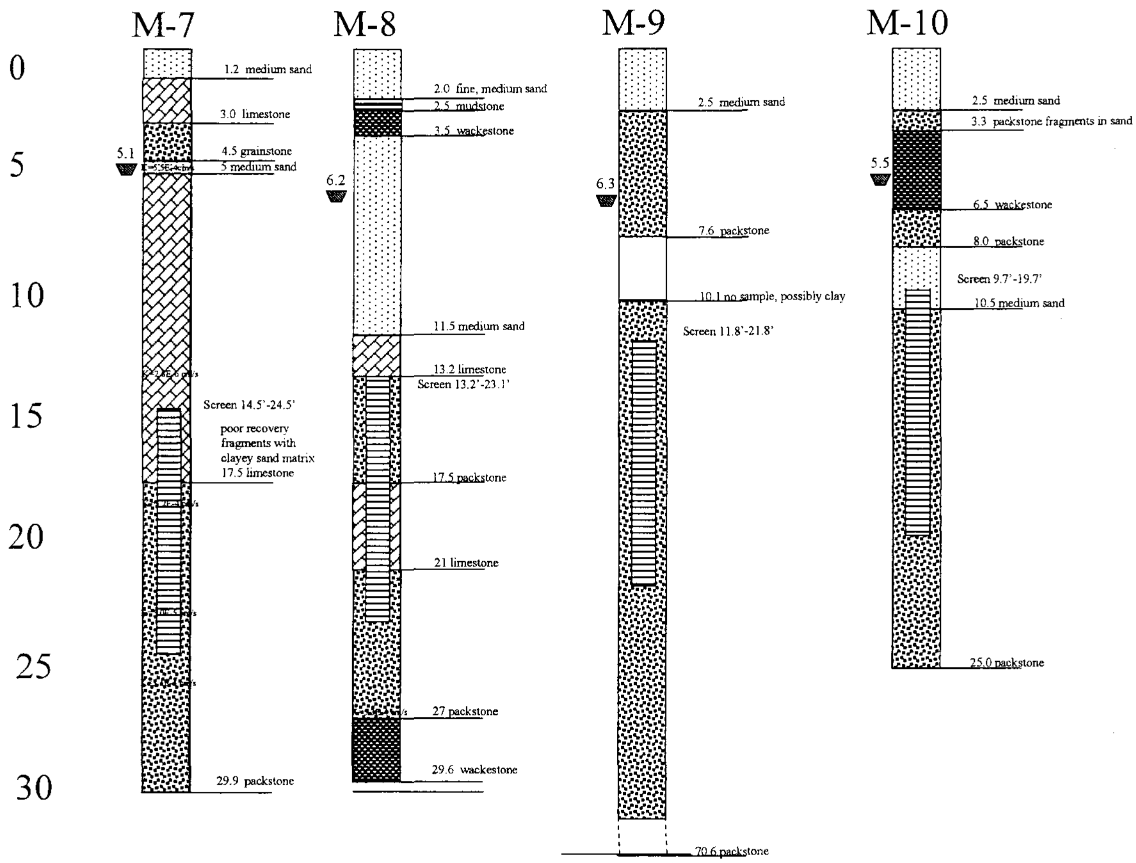

Figure 3- 9. Core descriptions of wells M-7, M-8, M-9, and M-10. Trapezoid indicates depth to water.

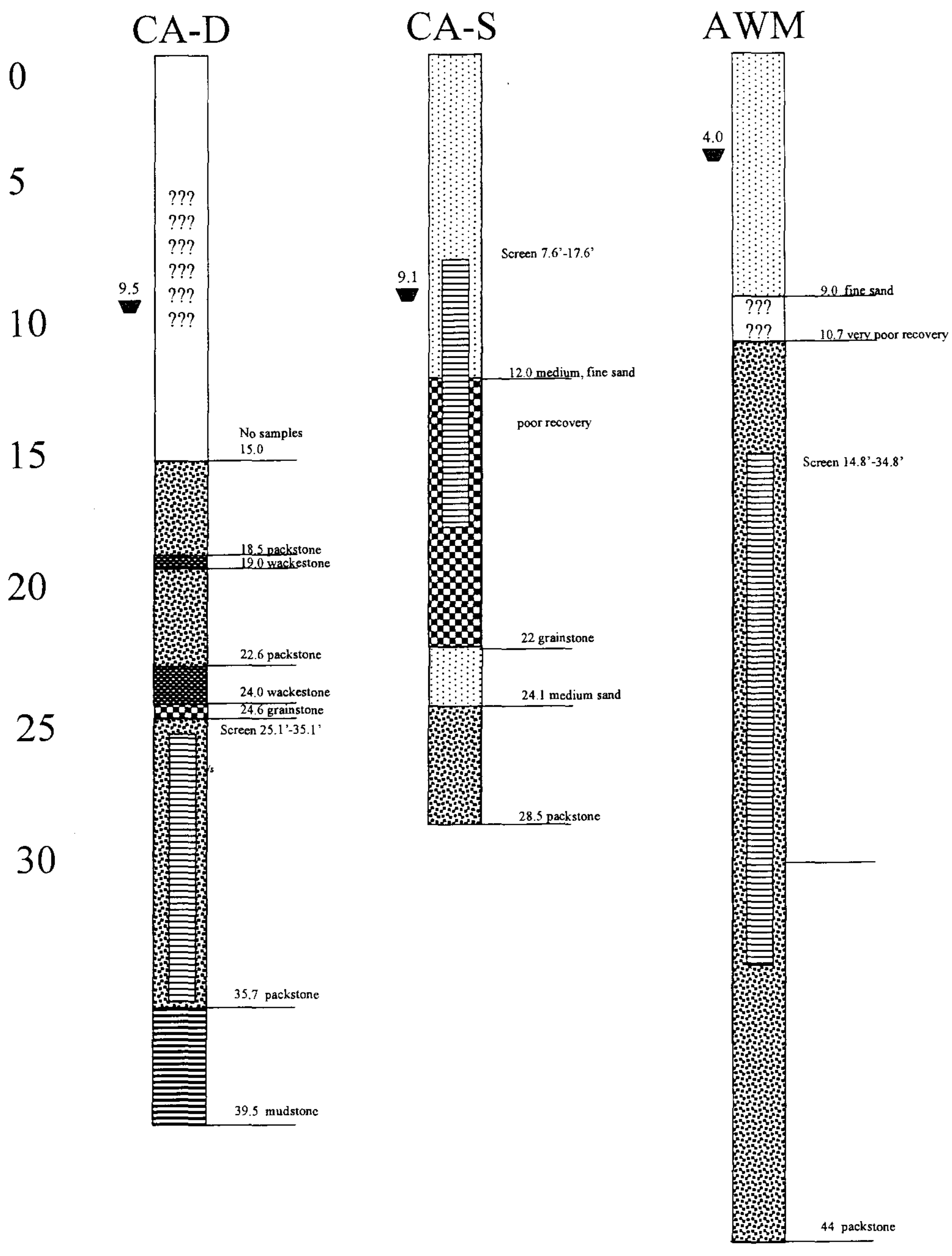

Figure 3- 10. Core descriptions of wells CA-D, CA-S, and AWM. These wells are at the Camp Azalea Road beyond the southern boundary of the park (CA) and north of the park in the Andrews Wildlife Management Area (AWM). Trapezoid indicates depth to water.

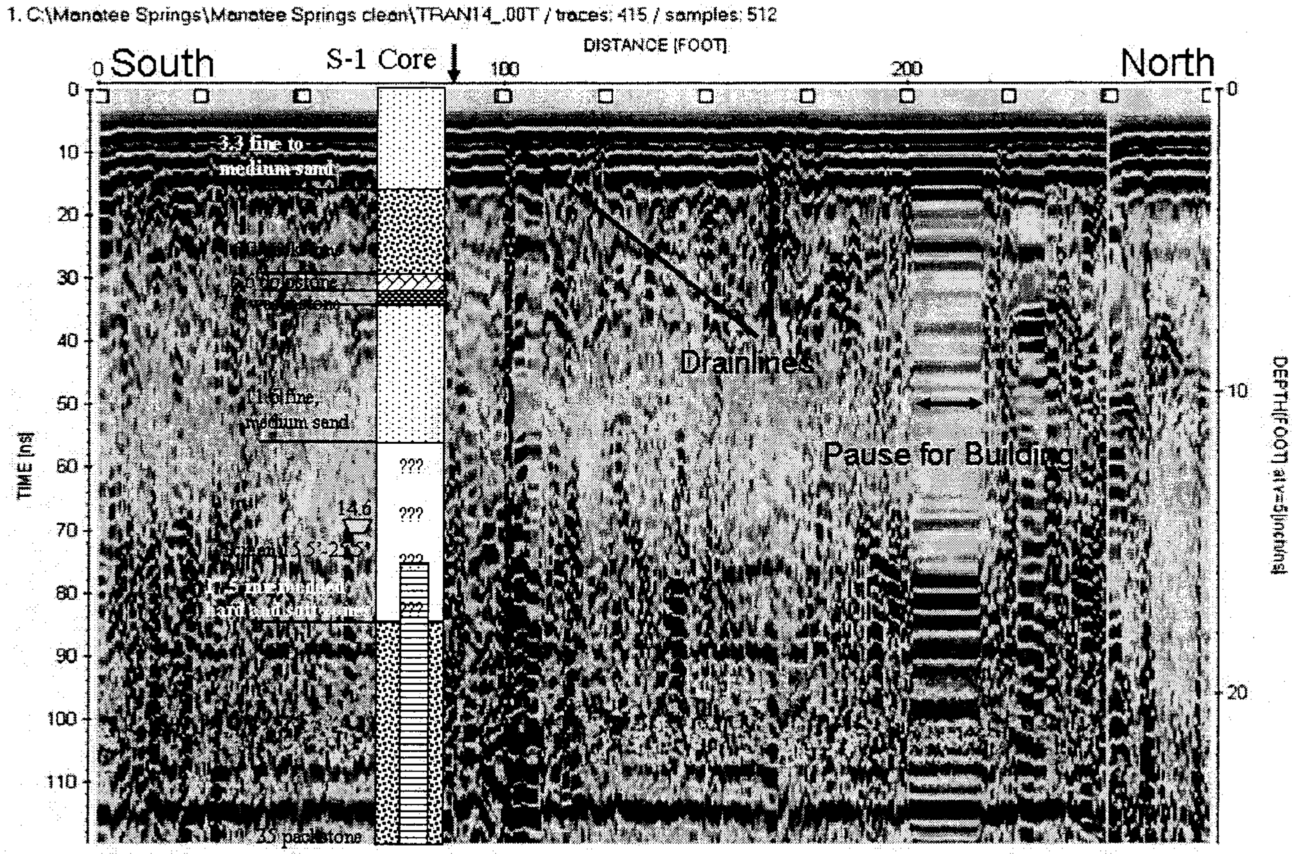

Figure 3- 11. Comparison between core description for S1 and GPR-transect 14.

Hydraulic Conductivity Testing

Sub-samples of the cores were taken and their laboratory hydraulic conductivity was determined by falling head permeameter tests. Results were also included in the Well Log data System. All observations were performed by or under the oversight under the oversight of a Ken Campbell, a professional geologist at the Florida Geological Survey.

Figure 3-12 shows the frequency distribution of the decadic logarithm of the valid measurements of hydraulic conductivities. The measurements are grouped by lithology. For this graph classifications “fine sand” and ”dolostone” with one sample each and mixed classifications were excluded.

The lithology described as “medium sand” was most variable, without a clear mode. The observed range of values between 1E-7 and 1E-1 cm/s is wider than the range of 9E-5 to 5E-2 suggested by Domenico and Schwartz (1990), suggesting that texture and grain size distributions between the samples may have differed significantly.

Hydraulic conductivity tests of most packstones and wackestones resulted in a hydraulic conductivity between 1E-5 and 1E-2 with a mode, average and median between 1E-4 and 1E-3 cm/s. Grainstones were slightly higher in hydraulic conductivity, because of a lack of low-conductivity samples. The frequencies of observed conductivities appear consistent with a log-normal distribution. The conductivity values fall into the lower range given for karst and reef limestone rocks (1E-4 – 2E+0 cm/s) (Domenico and Schwartz 1990). This is an indication that the measured conductivity values represented intact pieces of limestone without large secondary porosity. This view is supported by the observation that the highest observed rock hydraulic conductivity was for a sample with a “large vertical fracture”. Because fractures and solution channels as preferential flow paths occur on a larger scale than core samples, the effective hydraulic conductivity for the study site as a whole is expected to be higher (Benson and Yuhr, 1993).

The influence of depth on hydraulic conductivity is illustrated by Figure 3-13. The measured hydraulic conductivity is plotted as a function of the depth of the sample. No trends appear to be present for the lithological classifications given (all $R^2 < 0.2$).

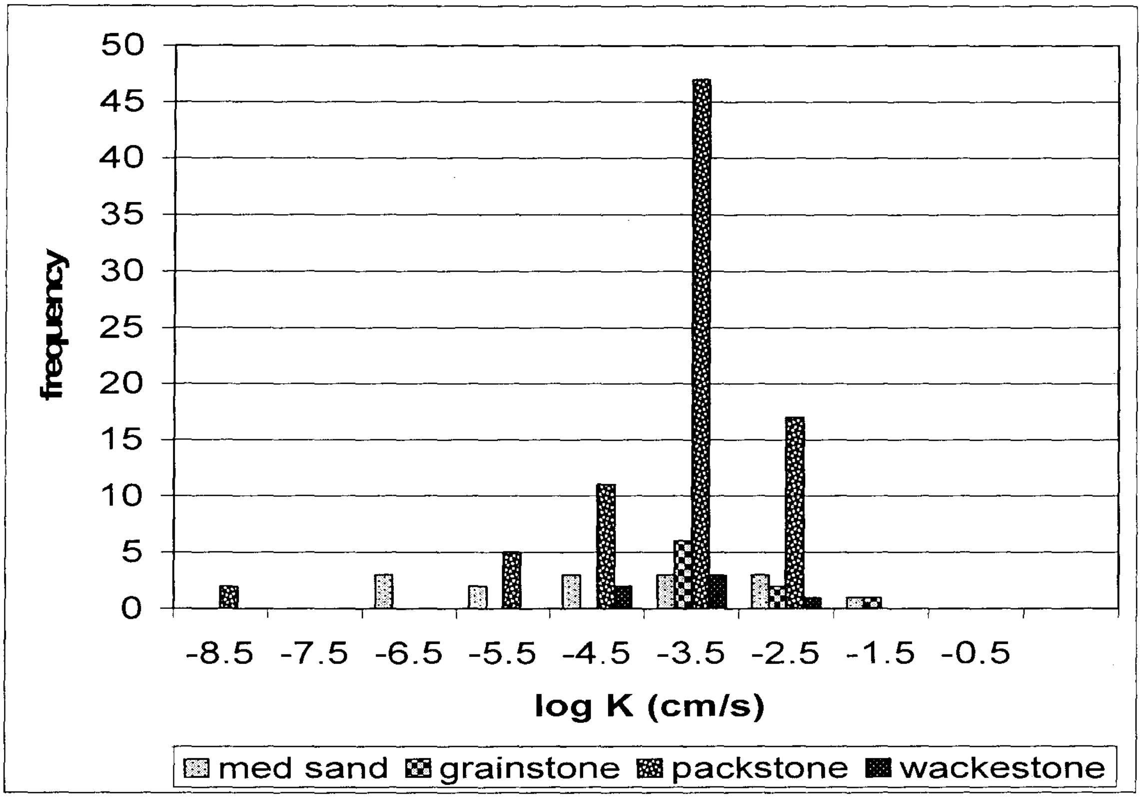

Figure 3- 12. Frequency distribution of log K (cm/s) for sampled material by lithological classification

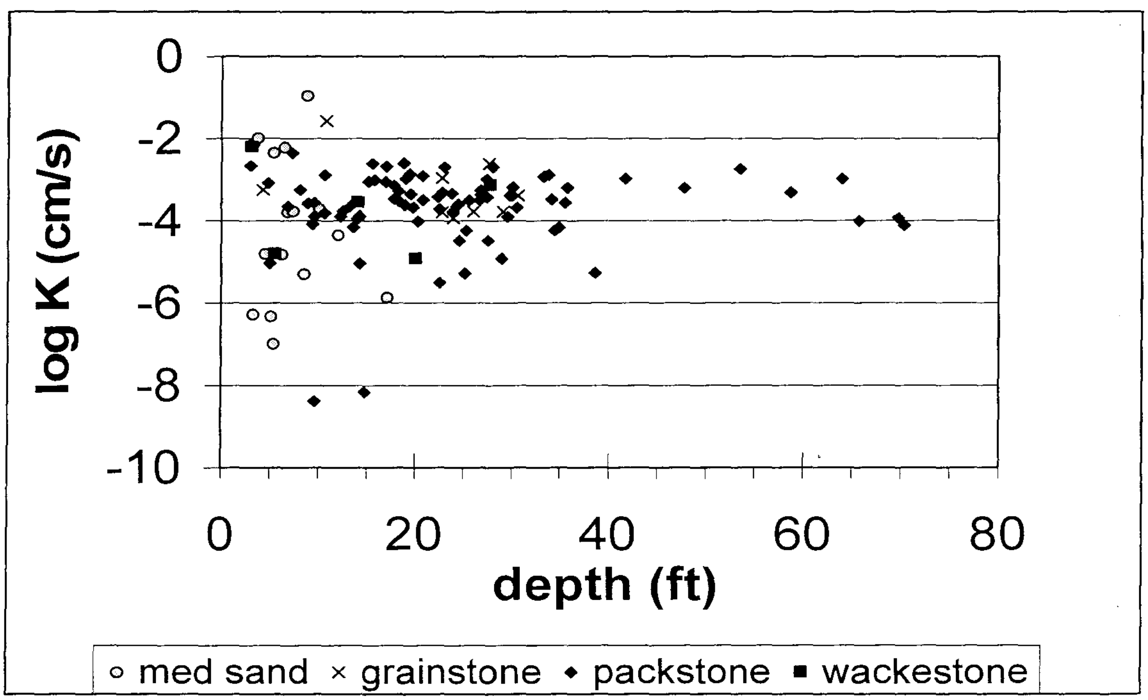

Figure 3- 13. Hydraulic conductivity plotted as a function of depth sampled. Note that all of the samples from a depth below 40 ft are from M-9.

Additional Background Data

Water Quality Data

Suwannee River Water Management District staff (Warren Zwanka) provided water quality data obtained from wells in the vicinity of the study sites from November 2002 through May 2003. Only a few wells were sampled as indicated in Table 3- 2. Limited as these numbers are, they suggest that nitrate-nitrogen concentrations are less than 0.2 mg/L in largely forested areas north and south of the park, but increase to beyond 0.2 mg/L at the eastern boundary of the State Park (wells -111325017 and -111325018) where there may be some influence from residential and agricultural land uses. None of the samples showed nitrate-nitrogen concentrations above 2 mg/L and total phosphorus above 0.2 mg/L.

Table 3- 2. Available monitoring wells of the SRWMD within the area of Figure 3-3 and measured concentrations between November 2002 and April 2004. Data from SRWMD.

Name	SRWMD_ID	lat (degree)	long (degree)	NO3-N (mg/L)	Ptot (mg/L)	Sample Date
CA-D	-121302011	29.47334	82.97908	0.07	0.005	2/21/2003
CA-S	-121302010	29.47335	82.97912	0.114	0.18	2/21/2003
AWM	-111312001	29.53999	82.96612	0.035	0.08	4/1/2003
	-111325008	29.49614	82.96516			
	-111325016	29.49642	82.96516			
	-111325017	29.48869	82.96408	1.21	0.122	1/27/2004
	-111325018	29.49645	82.96495	0.221	0.018	1/27/2004
	-111327003	29.49916	82.99393			
	-111335002	29.48944	82.97311			
	-111335006	29.48598	82.97362			
	-111336004	29.48485	82.96657			
	-111336005	29.48472	82.96677			
	-111429006	29.49017	82.9384			
	-111430014	29.48993	82.95196			
	-111430015	29.49389	82.95361			
	-111430016	29.49278	82.95333			

Hydrological Data

SRWMD staff (Tom Mirti) provided hourly rainfall data and gage data for Manatee Springs (daily) and the Suwannee River at Manatee Springs (hourly). The values between January 1, 2002 and February 1, 2004 are shown in Figure 3-14. Spring and river gage data show good agreement with each other, generally within the range given by the tidal variations in the Suwannee River. Above a stage of three feet, the tidal variations become much less pronounced, and during the high–water period between March 10, 2003 and May 06, 20003 very little tidal influence is apparent. During a site visit at the peak of the flood, most of the monitoring wells at Magnolia II were observed to be covered by water.

Rainfall intensities at Manatee Spring show little relationship to the gage data. In 2003, intensities larger than 1 inches/hour as part of a rainy period were followed by increases in water levels by at least a foot. The same effect did not occur in 2002. Total rainfall was 50.7 inches in 2002 and 49.8 inches in 2003.

Park Attendance

The State Park Reservation System (John Reynolds) provided attendance data for the campgrounds at Manatee Springs State Park. These figures are plotted in Figure 3-15 for the time period November 1, 2002 through February 2, 2004. Noticeable are peaks of campground attendance on weekends with much lower uses during the week days. The generally lower usage since September 1, 2003 may reflect the closing of Hickory campground for renovations after the Labor Day weekend.

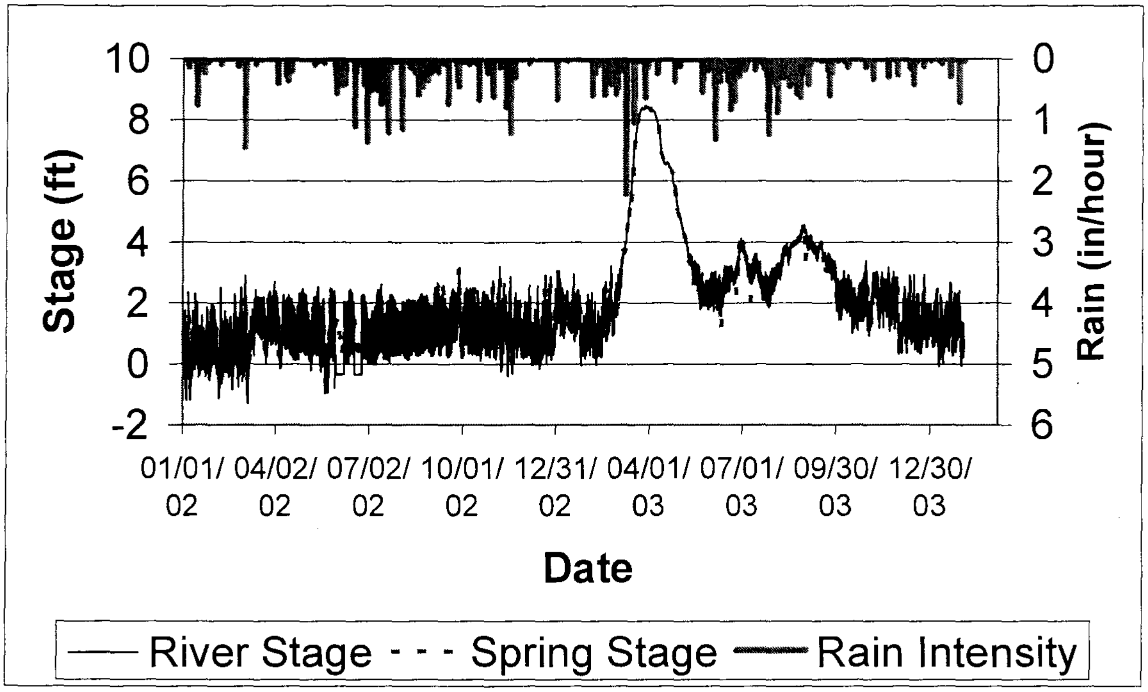

Figure 3- 14. River and spring gage data and rain intensity between 01/01/2002 and 02/01/2004. River gage data are corrected for the gage error found during surveying. Data from SRWMD.

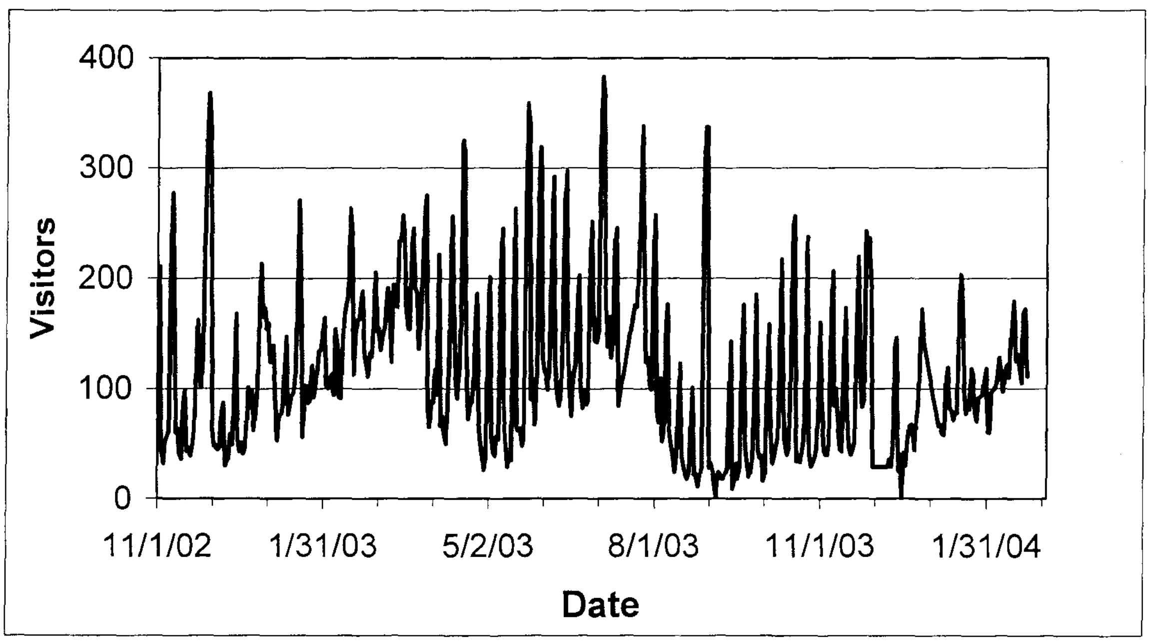

Figure 3- 15. Campground attendance in Manatee Springs State Park. Data from DEP-Division of Recreation and Parks.

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Chapter 4 Manatee Springs Onsite Sewage Treatment and Disposal System Study: Groundwater Quality and Tracer Tests

By

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Abstract

Karst geology, which is widespread in Florida, is typified by the presence of solution channels (conduits), sinkholes and springs in limestone bedrock. A layer of sand frequently covers the bedrock. These karst features allow rapid transport of water and contaminants between the surface water and groundwater. In the context of onsite sewage treatment and disposal systems (OSTDS), the overlying sand and the limestone have distinct functions. Sandy, unsaturated soils on the top are expected to provide treatment for onsite sewage, while the conduit-ridden limestone aquifer will affect little attenuation, mainly transporting treated effluent to springs or other surface waters. The goal of this study was to evaluate the connectivity between the overlying sandy soil and the karst aquifer. Very few specific standards for the location and installation of OSTDS in karst regions exist in Florida or elsewhere in the United States. The hypotheses are that rapid movement of effluent through the soil and underlying karst bedrock occurs and that this will allow nutrients and pathogens to flow into and through the aquifer without much attenuation.

Two conventional septic systems at the Magnolia and Hickory campgrounds in Manatee Springs State Park, Florida, were studied to ascertain the impacts on the

groundwater quality and their effectiveness at removing nutrients and fecal coliform in a karst environment. The Hickory site is an upland hammock environment with a deep water table and the Magnolia site is representative of a riverfront environment with a shallow water table. The hypotheses were tested by comparing water quality of monitoring wells near OSTDS to background water quality and by conducting tracer tests. Monitoring wells were installed downstream of drainfields. Nitrate, nitrite, ammonia, total Kjeldahl nitrogen (TKN), phosphorus and fecal coliform bacteria were monitored over a one-year period. The chemical tracers sulfur hexafluoride and fluorescein were used to establish connections between the drainfields and monitoring wells and to estimate travel velocities of septic system effluent in groundwater.

The results of this study confirmed fast connections between the surficial soils and the underlying karst aquifer at both the OSTDS sites. Tracer was observed at each site in monitoring wells within hours of the injection into the drainfields. Flow velocities, as determined by travel times to individual monitoring wells, were in tens of feet per day. At Magnolia campground, flow velocities varied from 5 to 100 ft/day and at Hickory campground they varied from 1 to 280 ft/day. Elevated nutrients were found in wells surrounding the septic systems, with nitrate-nitrogen concentrations in impacted wells as great as 20 to 60 mg/L at both the Magnolia and Hickory sites. Well M8 was the most impacted at Magnolia, with concentrations ranging up to 55 mg/L nitrate-nitrogen, 0.92 mg/L total phosphorus and 934 fecal CFU/100 mL. Well S1 was the most impacted at Hickory, with concentrations ranging up to 56 mg/L nitrate-nitrogen, 4.89 mg/L total phosphorus and 99 fecal CFU/100 mL. The greatest concentrations observed in background wells were only 1.61 mg/L nitrate-nitrogen, 0.474 mg/L total phosphorus and less than two fecal CFU/100 mL. The most elevated nutrient concentrations were found directly in the flow path of the effluent as indicated by the tracer experiments. The conclusion of this study is that the proximity and connectivity of the surficial soils and the underlying karst aquifer limits the ability of conventional OSTDS to attenuate nutrient and pathogen concentrations and allows rapid transport in the direction of the nearest downstream surface waterbody or spring. The Department of Health should investigate and recommend alternative treatment options in karst environments. Alternatives to conventional OSTDS are already commercially available and used extensively in the Florida Keys and in limited use statewide. The results from this study could be applicable also to other waste disposal methods that do not remove nutrients.

Introduction

The Suwannee River has experienced increasing concentrations of nutrients over the last 20 years (DEP 2001). Increased nutrients in water can cause eutrophication, excessive plant growth and subsequent die-off. The Suwannee River Water Management District (SRWMD), the United States Geological Survey (USGS) and the Florida Department of Environmental Protection (DEP) have monitored this trend. The lower Suwannee River has been included on the State's impaired water or 303(d) list for nutrients. Nitrogen and phosphorus are listed as co-limiting nutrients (DEP 2002). Basin wide, the contribution of onsite sewage treatment and disposal systems (OSTDS) to the nitrate problem is below 10% compared to other sources, in particular agriculture and atmospheric deposition (Katz et al. 1999; DEP 2001). However, it may be locally significant in areas around springs where housing density is higher (DEP 2001).

The Lower Suwannee River Basin is underlain by Ocala limestone, which is karst in nature. Karst geology is typified by the presence of solution channels (conduits), sinkholes and springs that are formed when acidic rainfall dissolves the underlying carbonate bedrock. These karst features have been shown to rapidly transport contaminants to and in the underlying groundwater (Price 1988). Because of this rapid movement, there is a high likelihood that septic tank effluent will not be attenuated other than by dilution. In areas with discontinuous limestone, Department of Health (DOH) policy requires drainfield infiltration surfaces to be located at least 3.5 feet above the limestone (DOH 1999). While this is believed to allow functioning of drainfields, it also allows effluent to enter the karst groundwater flow system. A goal of this study was to examine the "connectivity" between the overlying sandy soil and the underlying karst aquifer.

This study attempted to quantify the groundwater impacts from installing conventional OSTDS in karst regions along the Suwannee River. It also serves as a comparison to conventional OSTDS installed in different hydrogeological conditions, such as barrier islands and areas of high water table near seasonally inundated areas (Harden et al. 2003; Corbett et al. 2000). Since karst conditions occur in large areas of Florida, the results of the study shed light on the possible effects of the current disposal methods in many areas of the state.

The current methods being used for disposal need to be evaluated to determine if adequate removal of pathogens and nutrients are being accomplished using conventional OSTDS. This is of particular concern with regards to nitrates, which result from oxygenation of ammonia and other reduced forms of nitrogen in septic tank effluent in the soils surrounding the drainfield. Because drainfields and the adjacent soils provide limited nutrient reduction capacity, density of OSTDS has been discussed with the goal of meeting the drinking water standard of 10 mg/L nitrate-nitrogen in down gradient drinking water sources (Mayer 1999). This standard is not sufficient for ecologically sensitive areas where eutrophication can occur due to elevated nutrient levels. Recently, EPA has recommended ecologically based criteria of 0.04 mg/L for total phosphorus and 0.90 mg/L for total nitrogen for rivers and streams in the ecoregion that encompasses most of Florida (EPA 2002).

The hypothesis that rapid impacts occur from conventional OSTDS in a karst environment was tested by comparing water quality of monitoring wells near the OSTDS to those representing background water quality. Tracer and permeameter studies were used to interpret the water quality data results. The results were compared to the results of previous OSTDS studies in Florida.

Well siting and installation are critical to being able to determine the flow direction and speed of contaminants moving away from the septic system. The karst bedrock in the area is known to contain solution channels, paleo-sinkholes and other features that are not always visible by surface examination. These features are thought to influence the vertical movement of septic tank effluent through the soil. In order to identify these features a non-destructive method, ground penetrating radar (GPR), was used. Ground penetrating radar has been successfully used in the region to identify these hidden features (Collins et al. 1990; Pucket et al. 1990). The results of the GPR survey were used to locate solution channels within the karst aquifer and site monitoring wells into them. Series of successive monitoring wells in a line between the drainfield and surface water features were installed to monitor water quality along the presumed direction of flow.

Nutrient and fecal coliform samples were taken on a semi-quarterly basis from the monitoring wells. In addition to the monitoring wells installed at the two study sites and the background sites, surface water samples were taken from the sinkholes, Sue Sink and Catfish Hotel, as well as at the spring. The water quality of the monitoring wells in proximity to the septic systems was compared to background monitoring wells and the surface water of the spring and sinks. Two chemical tracers, sulfur hexafluoride and fluorescein dye, were used to evaluate the subsurface flow direction and velocity of the septic effluent, determine if the septic drainfield and monitoring wells located within the karst aquifer were hydraulically linked, and see if elevated nutrient concentrations were influenced by such linkage.

Sulfur hexafluoride (SF_6) is a water-soluble gas that is biologically and chemically inert, has a low background atmospheric concentration (10^{-15} mol/L), and can be detected at extremely low concentrations (10^{-16} mol/L) (Wanninkhof et al. 1985). The potential of SF_6 as a geothermal and groundwater tracer has been reported (Upstill-Goddard and Wilkins 1995; Wilson and Mackay 1993) and it has been used successfully in karst limestone (Dillon et al. 1999) and shallow, sandy aquifers (Corbett et al. 2000).

Sodium fluorescein ($C_{20}H_{10}O_5Na_2$), a highly water soluble fluorescent dye, is bright yellow-green to the eye and has a maximum excitation wavelength of 491 nanometers (nm) and a maximum emission wavelength of 513 nm. Many groundwater-tracing studies have employed this dye since it is inexpensive, easily detectable, non-toxic, and stable over time (Gasper 1987; Smart and Laidlaw 1977). However, the dye will break down if exposed to direct sunlight. Although used frequently as a tracer in onsite systems, fluorescein is known to bind to organic matter in soils (Trudgill 1987; Omoti and Wild 1979; Smart and Laidlaw 1977) and also to alumina and carbonates (Kasnavia et al. 1998).

Methods

Site Selection and Description

Both study sites were located in campground areas within the Manatee Springs State Park. The State Park location had the advantages of being relatively isolated from outside sources of groundwater pollution, guaranteed access throughout the study, septic systems that were continuously in use, and the availability of local hydrologic data from the Suwannee River Water Management District. Water quality data from wells in undeveloped wooded areas on the park boundary served as background levels for the nutrient and fecal coliform measurements.

The two OSTDS were located in distinct hydrogeological settings. The Magnolia site in the Magnolia II campground is located in close proximity to the river and both the OSTDS and the bathhouse were located on a mound. The situation of a mounded (elevated above natural ground surface) drainfield is frequently encountered in developments along the riverfront. The top of the drainfield mound is barely above the 10-year floodplain elevation of 13 feet above the Suwannee River (SRWMD, undated). The *Soil Survey of Levy County, Florida* maps this location as Otela-Tavares Complex, with 1 to 5 percent slopes. Otela-Tavares soils are associated with sandy karst uplands. Towards the river, soils transition to Holopaw-Pineda Complex, frequently flooded and along the river the soil is mapped as Chobee-Gator complex, frequently flooded. All these soils are described as very deep (>80 inches). The Chobee-Gator complex includes muck at the surface resulting from the high degree of wetness. The drainage grades from moderately well drained for Otela-Tavares to very poorly drained along the river. (Slabaugh et al. 1996)

The Hickory site, located in the Hickory campground, has a conventional OSTDS consisting of an in-ground septic tank and several trenches as drainfield. The water table is at least ten feet below ground surface in non-flood conditions. The Manatee Spring cave system is approximately 60 to 100 feet below the ground surface (Sallot 1999). The soils in this area are quite different from those at the Magnolia site. The *Soil Survey of Levy County* has identified the soils in the area as Jonesville-Otela-Seaboard complex, 1 to 5% slopes. The soils of this complex are associated with karst uplands, well to moderately well drained and very shallow to very deep. Depending on the soil, limestone bedrock may be encountered at a depth between 17 and 66 inches. (Slabaugh et al. 1996).

The Official Soil Series descriptions for these soils were included in chapter 2. Coring during well drilling allowed further characterization of the subsurface as illustrated by the lithologic profiles in chapter 3. Limestone rocks were visible on the surface in some areas.

Ground-Penetrating Radar Survey

Ground-penetrating radar (GPR) was used at Manatee Springs State Park in August 2001 to survey two areas to locate, if present, depths to limestone and subsurface karst features (sinkholes and solution pipes). Details of this survey were discussed in chapter 2. Mark Hooks of DOH attended the Hickory survey and used the GPR-indicated large anomaly close to the intersections of two trenches to site well S-1.

Well Installations

Both sites were instrumented with 10 slotted wells for groundwater quality and tracer sampling (Figures 4-1 and 4-2). Drilling, as discussed in chapter 3, was performed without the use of driller's mud in order to minimize contamination of water quality samples. Wells were installed to a depth of at least 10 feet below the water table at the time of installation. The wells were constructed with 10 feet of 2-inch diameter PVC slotted well screen, silica sand filter pack and Bentonite grout.

At Magnolia, the wells fan out between the drainfield and the bank of the Suwannee in the presumed direction of groundwater flow. Well M1 is in the lower portion of the mound slope. Wells M10, M4, and M6 are close to the cypress marsh in the floodplain of the Suwannee River.

At Hickory, the wells were installed in the presumed flow paths of wastewater from the septic tank and trenches to either one of the sinks. Well S1 was installed in an area where the GPR-study had shown anomalies which were interpreted as a sinkhole or solution pipe. During well drilling, four feet of rock were encountered to a depth of seven feet. This suggests that the anomalie, such as a solution cavity did not extend all the way to the surface. S2 was installed at the end of a drainfield trench. C1 was installed on the lip of the slope leading down to Catfish Hotel and S3 was installed on the lip of the slope leading to Sue Sink.

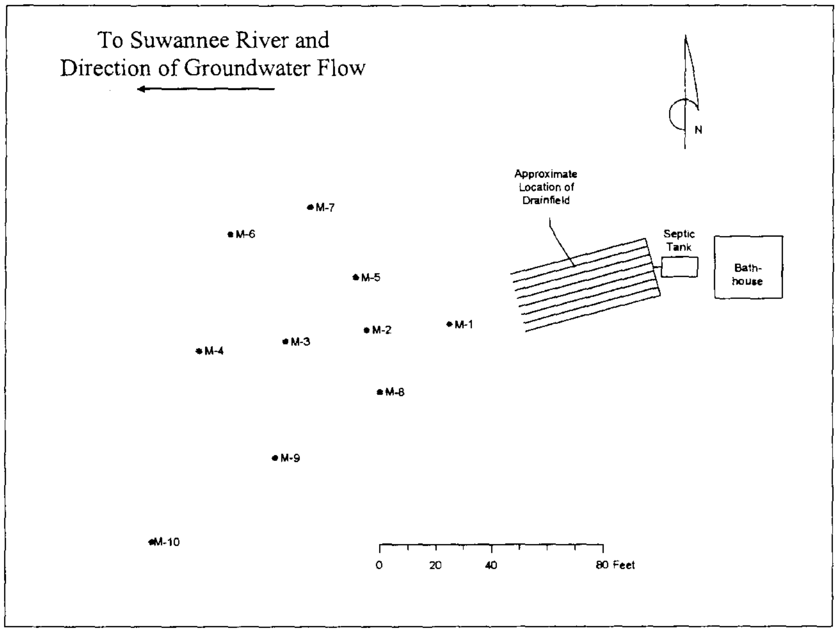

Figure 4- 1. Study site behind the Magnolia II campground bathhouse.

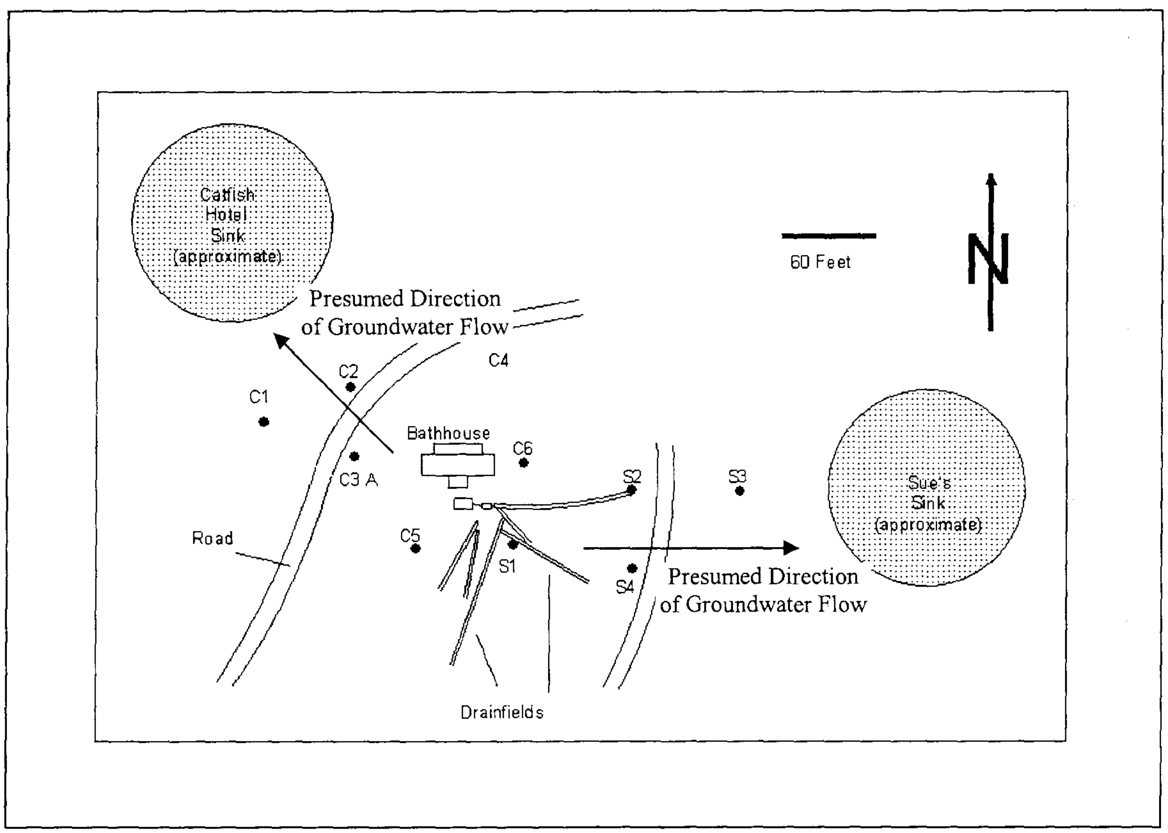

Figure 4- 2. Study site at Hickory campground bathhouse.

Tracer Injections

The injection solution was added by gravity feed into an opening in the pipe that connects the septic tank to the distribution box of the drainfield. The opening was sealed after the injection. This avoided dilution of the injection slug in the septic tank. Prior to each injection, background samples were collected from the well field. The Magnolia site was injected on May 24, 2003, with a solution consisting of 500 grams (g) of fluorescein dye dissolved into approximately 50 gallons of tap water that was bubbled with 99.8% pure SF_6 (Scott Specialty Gases) for at least 45 minutes. The injection slug was added to the drainfield over a 45-minute period by gravity feed while the solution was gently bubbled with SF_6 to counteract any SF_6 degassing. An additional 5-6 gallons of tap water was used to rinse the container and added to assure that the injection solution was flushed from the distribution pipes into the drainfield. These same techniques were repeated at the Hickory site on July 4, 2003, except that the injection time was decreased to 20 minutes. Three samples were taken from each injection slug during the injection period. The average SF_6 concentrations and standard deviations of these three samples were 418 ± 13 micromoles/L (μM) at the Magnolia site and 379 ± 80 μM at the Hickory site. The averages and standard deviations of fluorescein concentrations in the injection slug were 3242 ± 73 mg/L at the Magnolia site and 2851 ± 26 μM at the Hickory site.

Sample Collection

All samples were collected using a battery powered submersible pump. At least three well volumes (usually between 12-20 gallons) were pumped prior to any sampling. The water was collected in buckets and dumped downstream of the well field at Magnolia site. At Magnolia, sampling commenced at the wells furthest away from the drainfield and ended with M1, closest to the drainfield. At the Hickory site, the purge water was dumped into an outside sink connected to the septic system and located behind the bathhouse. This prevented the purge water from percolating back into the well during sample collection and reintroducing any analytes. During the well purging, the pump started near the top of the water column and was moved downward so approximately a third of the water was pumped from the top section, a third from the middle section, and a third from the bottom of the well. Prior to sampling, the pump was moved back within approximately three feet of the top of the water column.

SF_6 samples were collected in 30-mL serum vials using a peristaltic pump. After purging the slotted well, a sample was pumped into a serum vial and allowed to overflow for at least three bottle volumes. The vial was then sealed with a rubber septa and a crimp cap. Since a small bubble is sometimes present, the samples were stored upside down until they could be extracted and analyzed, preventing loss of SF_6 in the bubble through the septa.

Samples for nutrient and fecal coliform bacteria were collected from the wells in containers provided by the analytical laboratory. These samples required a specified volume marked on the containers. Samples were analyzed by a DOH certified lab using standard methods (Appendix 2). Fluorescent dye samples were also collected with a peristaltic pump and stored in 100-mL amber polycarbonate containers.

Sampling Frequency and Duration

Sampling frequency for the tracers was greatest immediately following tracer injection for two reasons. First, immediately following injection, the tracer slug is most concentrated and it is possible to miss its passing through a sampling picket array entirely. As time passes, the tracer slug usually disperses and widens so change in maximum concentration becomes less of a factor. Second, nearer the time of injection, each day not sampled creates greater uncertainty. For example, if the wells are sampled on the first and third days after injection, and the peak actually passes on the second day, an uncertainty of 33% results. Thus, the uncertainty introduced by missing a single day of sampling at three days after injection is much larger than the uncertainty of skipping a day ten days after injection, when one day is only 10% of the elapsed time. During both tracer experiments, the wells were sampled several times a day for the first three days, then twice a day for the next three days, then every other day for several days. As more time passed since the tracer injection the sample frequency decreased. Appendix 1 tabulates tracer analysis results.

Samples for nutrient and fecal coliform bacteria were collected from the wells two times each quarter between February 2003 and January 2004. An additional sampling event occurred in May 2005. At Hickory, only the two wells with the highest nitrate-nitrogen concentrations were sampled after the closing of the campground in September 2003. Appendix 2 tabulates nutrient and fecal coliform results.

Sulfur Hexafluoride Sample Analysis

Sulfur hexafluoride samples were extracted as described by Dillon et al. (1999). A small bubble of 4 mL of ultra-high purity nitrogen was added to the samples using a syringe. Simultaneously, 3 mL of water from the sample was removed and discarded to allow room for the headspace. The serum vials were slightly over-pressurized with 1 mL of nitrogen to allow several injection volumes (100 uL or less) for the gas chromatograph (GC) to be pulled from each sample. After shaking for at least two minutes, this method extracts more than 95% of the SF_6 from a water sample. The lower quantitation limit of this technique is 10^{-12} moles/L (Dillon et al. 1999).

Samples were analyzed with a Shimadzu Model 8A gas chromatograph equipped with an electron capture detector. The gas chromatograph contained a stainless steel column (180 cm x 0.1 cm I.D.) packed with a molecular sieve 5A with 80/100 mesh.

Ultra-high purity nitrogen was used as a carrier with a flow of 25 mL/min. Column and detector temperatures were set at 90°C and 220°C, respectively.

Concentrations in the gas of the headspace or bubble, Cv, in parts per million by volume or μL/L of SF_6 were determined by reference to a 1.04 μL/L standard (Scott Specialty Gases). The standard was run at the beginning of each day, after every thirty sample injections, and at the end of the day. Headspace gas concentrations were converted to dissolved concentrations in the water, C, in units of μM or μmoles/L as shown below:

$$C = Cv * P / (R * T) \quad * E * 4/30$$

R is the gas constant from the ideal gas law (PV = nRT) in units of (L atm)/(mol K), P is the atmospheric pressure (1 atm), and T is temperature in degrees K. The parameter E is the extraction efficiency, assumed to be equal to 95% (Dillon et al. 1999).

Duplicates were collected for 10% of the samples. In addition, replicate injections were run on the gas chromatograph every tenth injection. Precision between duplicate samples and replicate injections were usually better than 10%.

Fluorescein Dye Analysis

The fluorescein samples were analyzed using a Turner Designs TD-700 Fluorometer, and concentrations determined using a calibration curve. The fluorometer used a 10-089 blue mercury vapor lamp, 10-105 excitation filter (486 nm), and 10-109R-C emission filter (510-700 nm), as specified by the manufacturer. The fluorometer was initially calibrated using fluorescein standards made with distilled water in the laboratory. The lower limit of detection was 0.005 mg/L. Precision between duplicate samples was better than 10% and the reproducibility of replicate analyses of the same sample was better than 5%. Calibration was checked several times daily by use of solid state standards.

Results

Sulfur Hexafluoride and Fluorescein Tracer Experiment at Magnolia II

Injection of the solution of SF_6 and fluorescein into the drainfield of the Magnolia II campground bathhouse took place on May 24, 2003 from 10:26 a.m. to 11:08 AM. The additional injection of 18-20 gallons of tap water used to rinse the container and flush the last of the tracer into the system was complete at 11:18 a.m. The midway point of the entire process, 10:52 a.m., was chosen as the starting time for the tracer injection in all calculations. The two tracers yielded very different results with an observed fluorescein peak occurring before an observed SF_6 peak in each well.

At 05:05 p.m. on May 24, 2003, approximately six hours (0.26 day) after injection, the solution was observed pooling on the ground approximately five feet in front of well M8. Apparently, a significant portion of the injection slug quickly exited the mounded drainfield and flowed laterally, below the surface towards well M8. By 05:45 p.m., the puddle had grown to approximately three by seven feet, with the edge just over three feet in front of well M8.

The first and the highest concentrations of Fluorescein were both found in wells on the south side of the well field. Fluorescein was first observed in well M8 at 0.66 day (0.40 mg/L), rising to the highest concentration observed in the experiment in any well, 11.0 mg/L, at 1.13 days (Figure 4- 3). The second highest fluorescein concentrations were observed in well M9, the next well towards the river on the south side of the well field. The first observance of 0.042 mg/L occurred at 0.88 day, with high concentrations of 5.60 and 5.62 mg/L measured at 1.60 and 1.70 days, respectively (Figure 4- 4).

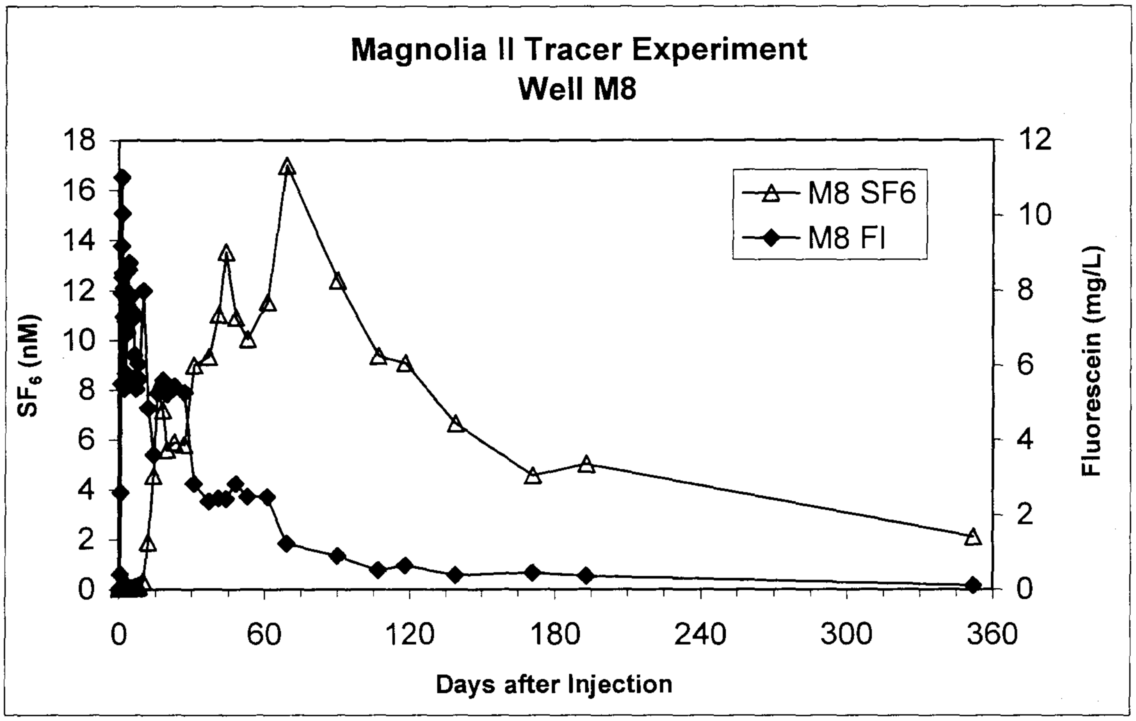

Figure 4- 3. Sulfur hexafluoride (open symbols) and fluorescein (closed symbols) data for well M8, where the highest fluorescein and SF_6 concentrations observed during the experiment occurred.

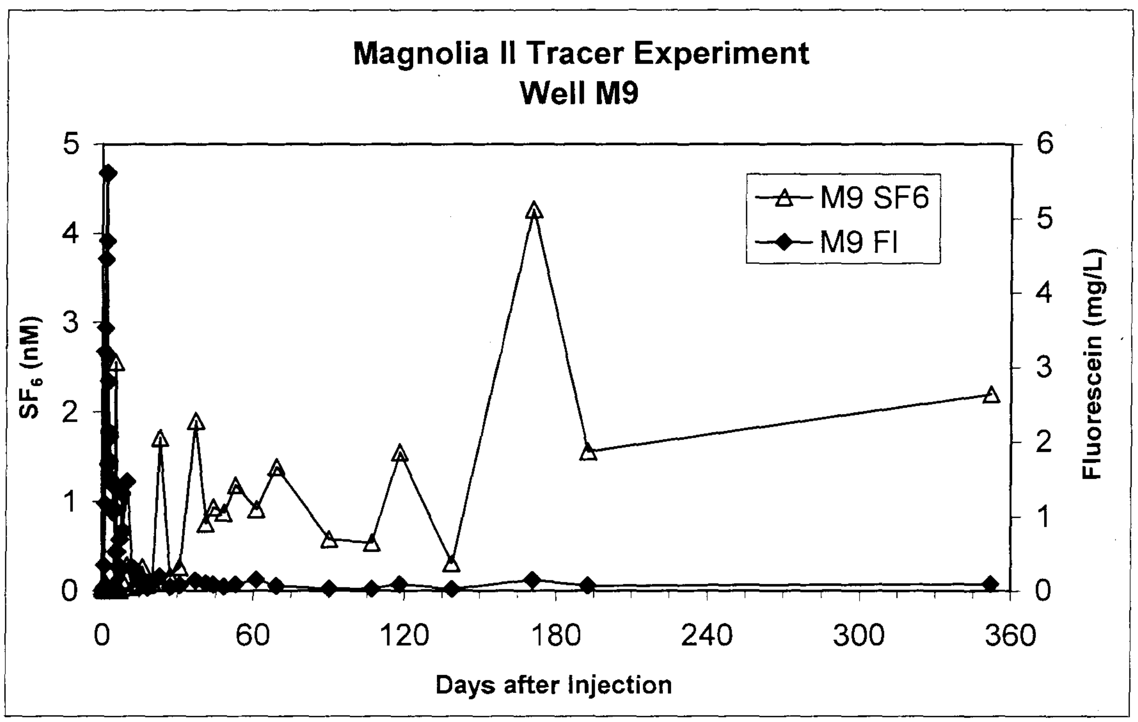

Figure 4- 4. Sulfur hexafluoride (open symbols) and fluorescein (closed symbols) data for well M9.

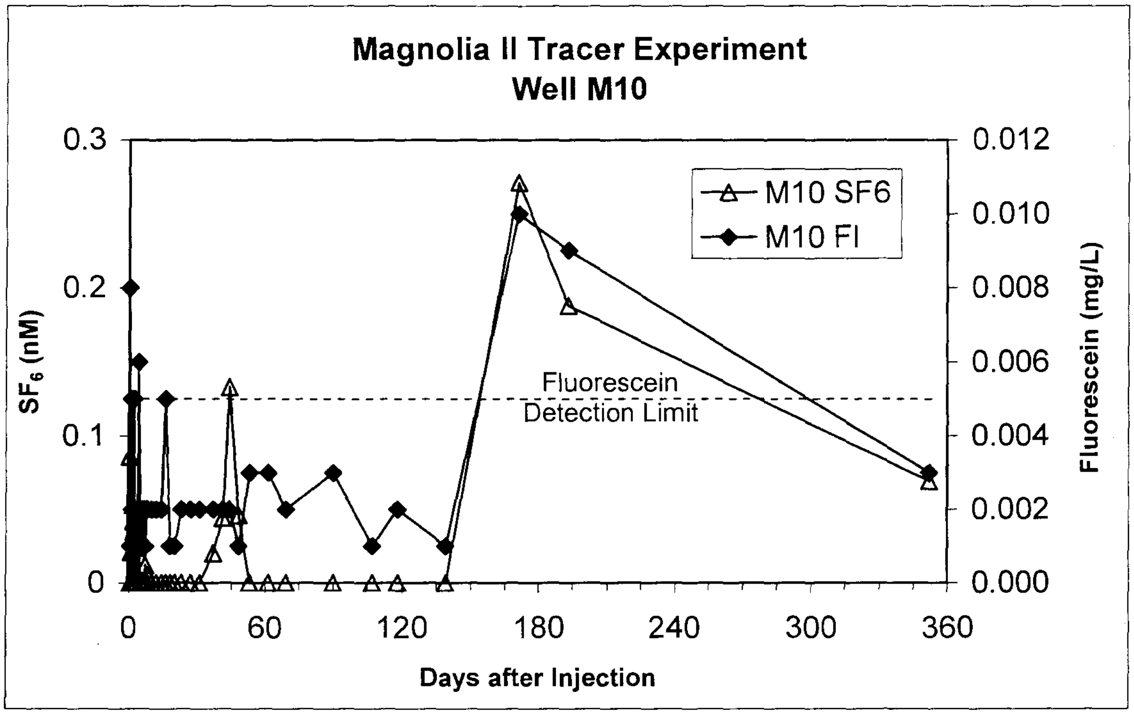

Figure 4- 5. Sulfur hexafluoride (open symbols) and fluorescein (closed symbols) data for well M10.

In the closest well to the river on the south side of the well field, M10, low concentrations of fluorescein, 0.008, 0.010 and 0.009 mg/L, respectively, were observed at 0.25, 171 and 193 days after injection (Figure 4- 5). Of all the wells, M10 had the smallest concentrations of SF_6 and Fluorescein, which indicates that well M10 was outside of the main effluent plume.

In the center of the well field, fluorescein was detected later in wells M1 and M2 than in well M3, even through M3 was further away from the drainfield. M1, the well on the drainfield slope, had an observed fluorescein peak of 1.45 mg/L at 18.09 days (Figure 4- 6). A larger fluorescein peak of 2.84 mg/L was observed at 22.94 days in well M2 (Figure 4- 7). Earlier, a fluorescein peak of 1.86 mg/L had been observed in well M3 at 2.19 days (Figure 4- 8).

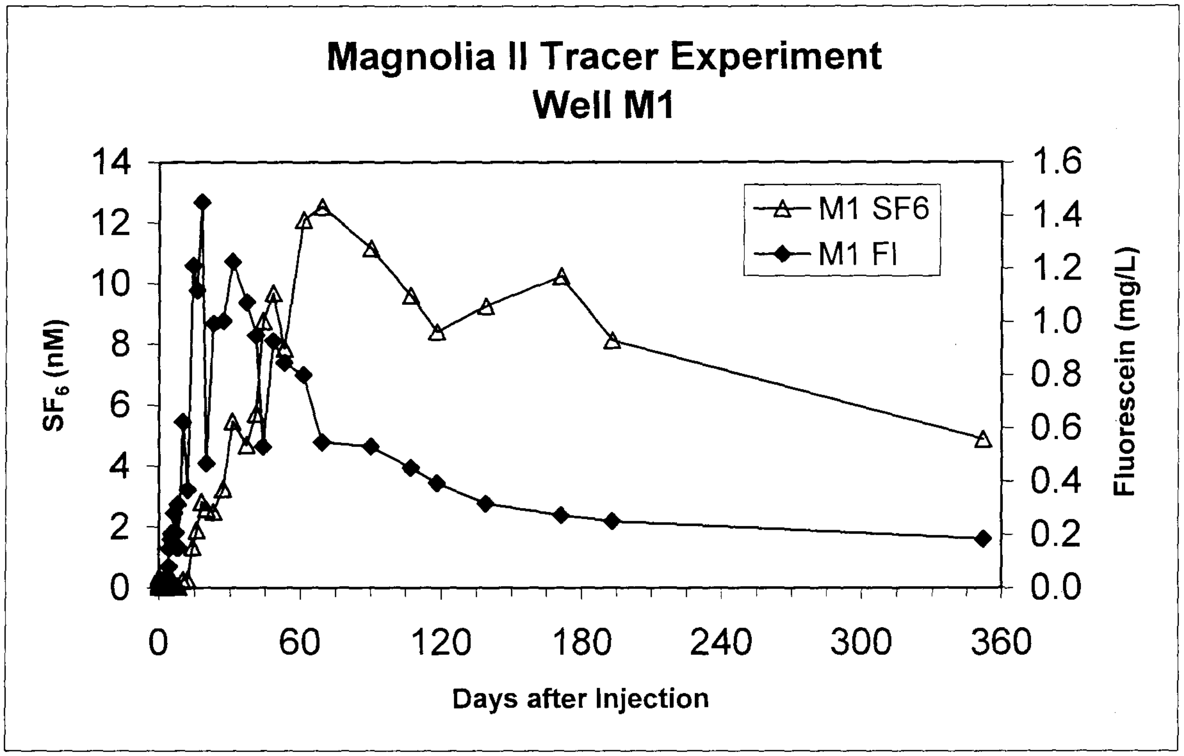

Figure 4- 6. Sulfur hexafluoride (open symbols) and fluorescein (closed symbols) data for well M1.

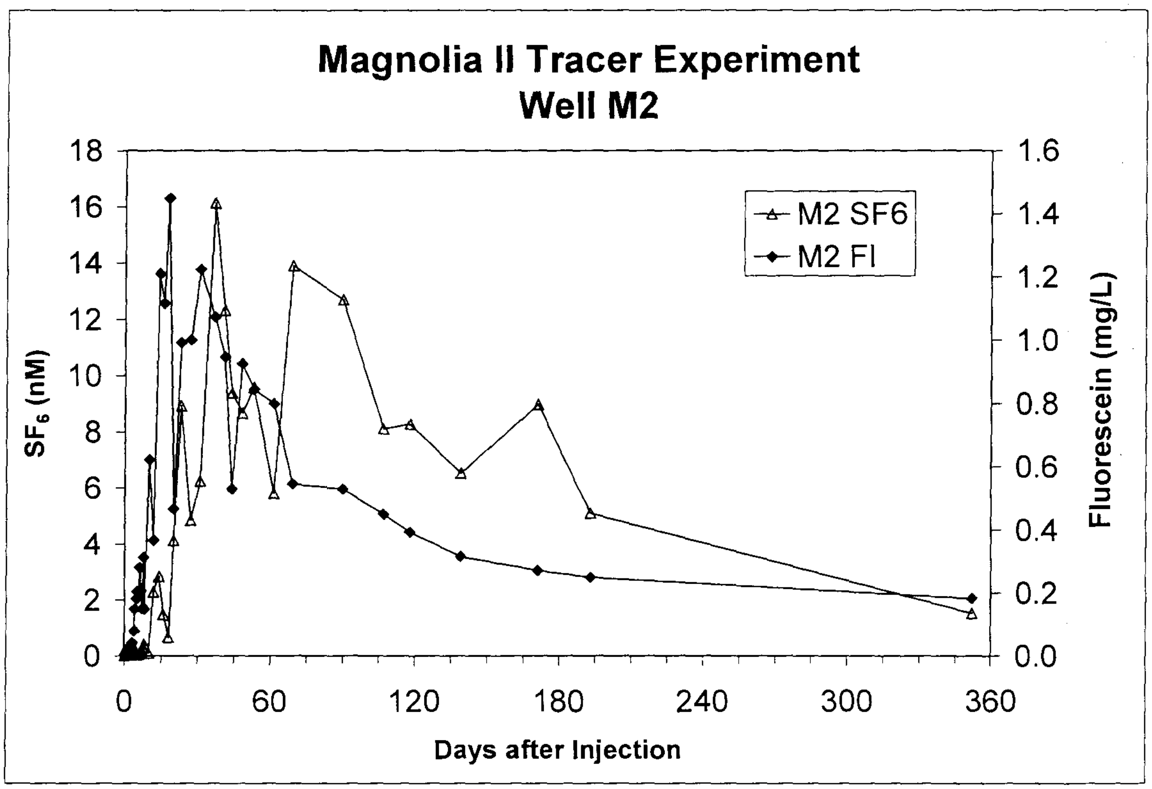

Figure 4- 7. Sulfur hexafluoride (open symbols) and fluorescein (closed symbols) data for well M2.

A small fluorescein peak of 0.060 mg/L, the second lowest among the Magnolia wells, was observed in well M4, close to the river, at 8.28 days (Figure 4- 9). The low concentration in well M4 may have been related to the fact that its screen was the deepest among all of the Magnolia wells.

On the north side of the well field, the well M5 showed the next peak in elevated fluorescein levels after M9. The first observation in M5 of 0.158 mg/L occurred at 0.80 days, with an observed high concentration of 1.31 mg/L at 2.19 days (Figure 4- 10). Well M6, closest to the river on the north side, had the next observed peak concentration of 0.36 mg/L at 3.16 days (Figure 4- 11), while well M7, closer to the drainfield, had a peak concentration of 0.51 mg/L at 10.02 days (Figure 4- 12).

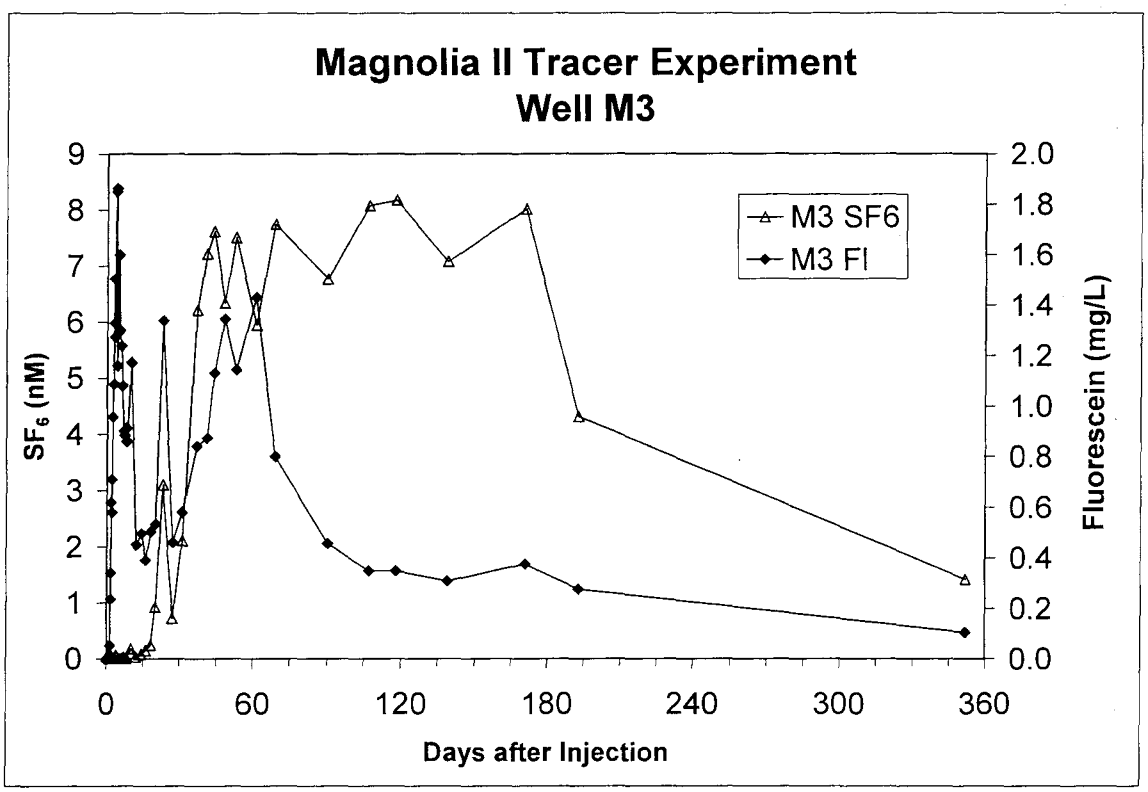

Figure 4- 8. Sulfur hexafluoride (open symbols) and fluorescein (closed symbols) data for well M3.

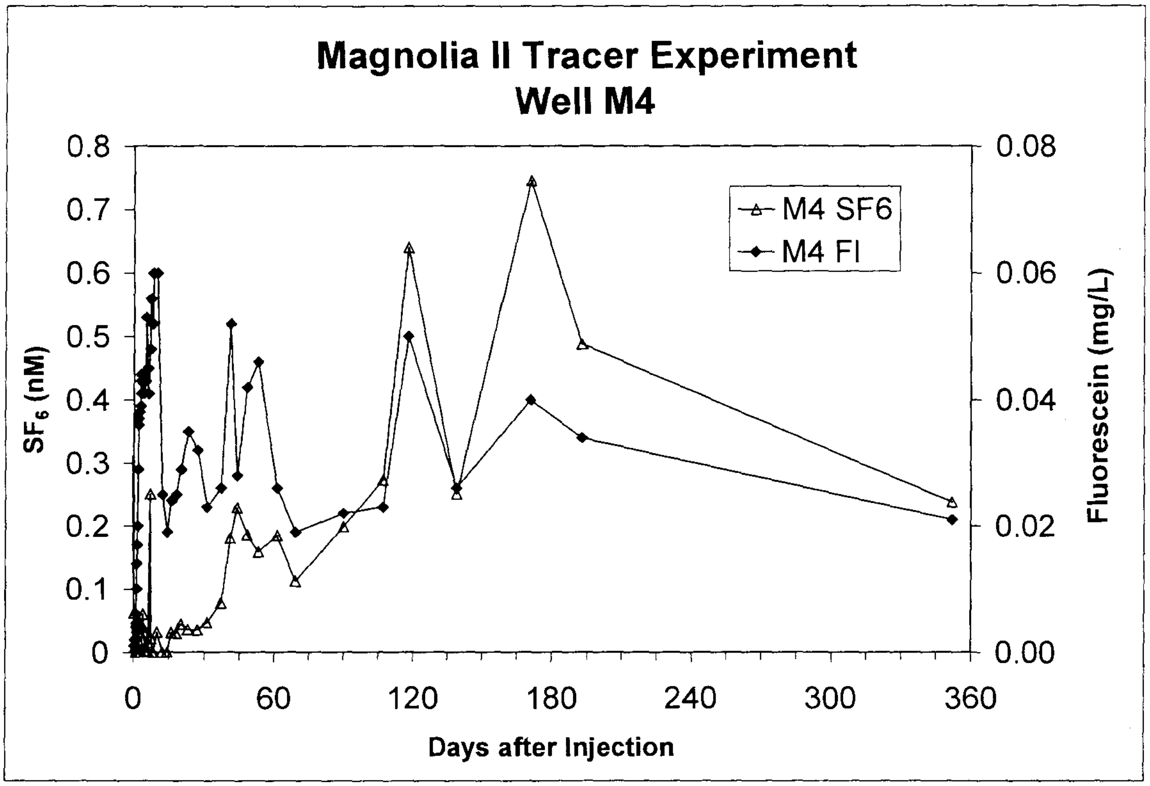

Figure 4- 9. Sulfur hexafluoride (open symbols) and fluorescein (closed symbols) data for well M4.

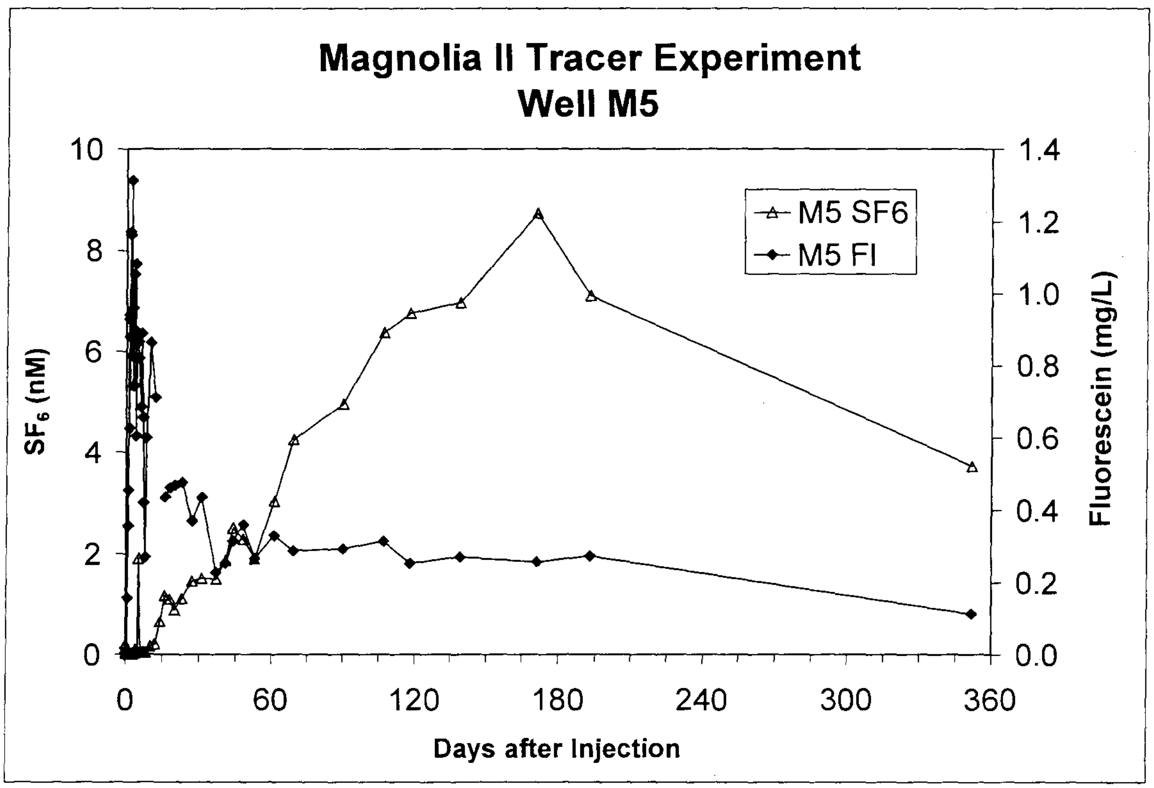

Figure 4- 10 Sulfur hexafluoride (open symbols) and fluorescein (closed symbols) data for well M5.

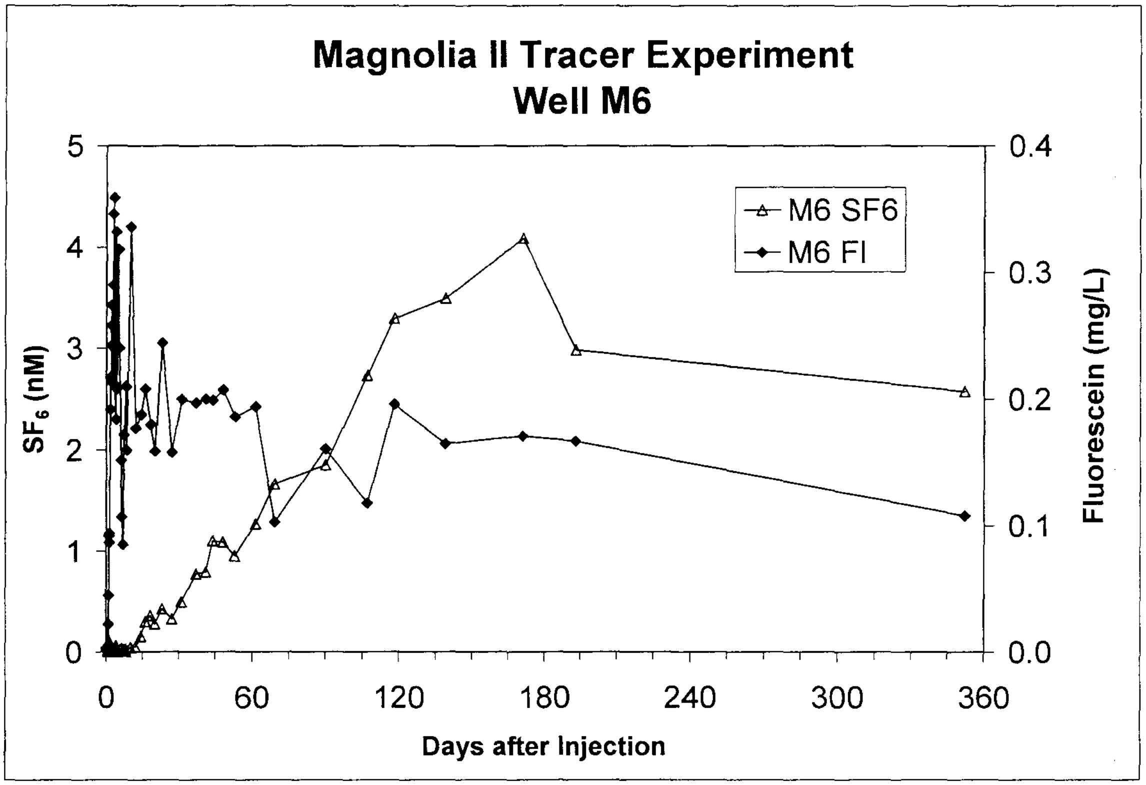

Figure 4- 11. Sulfur hexafluoride (open symbols) and fluorescein (closed symbols) data for well M6.

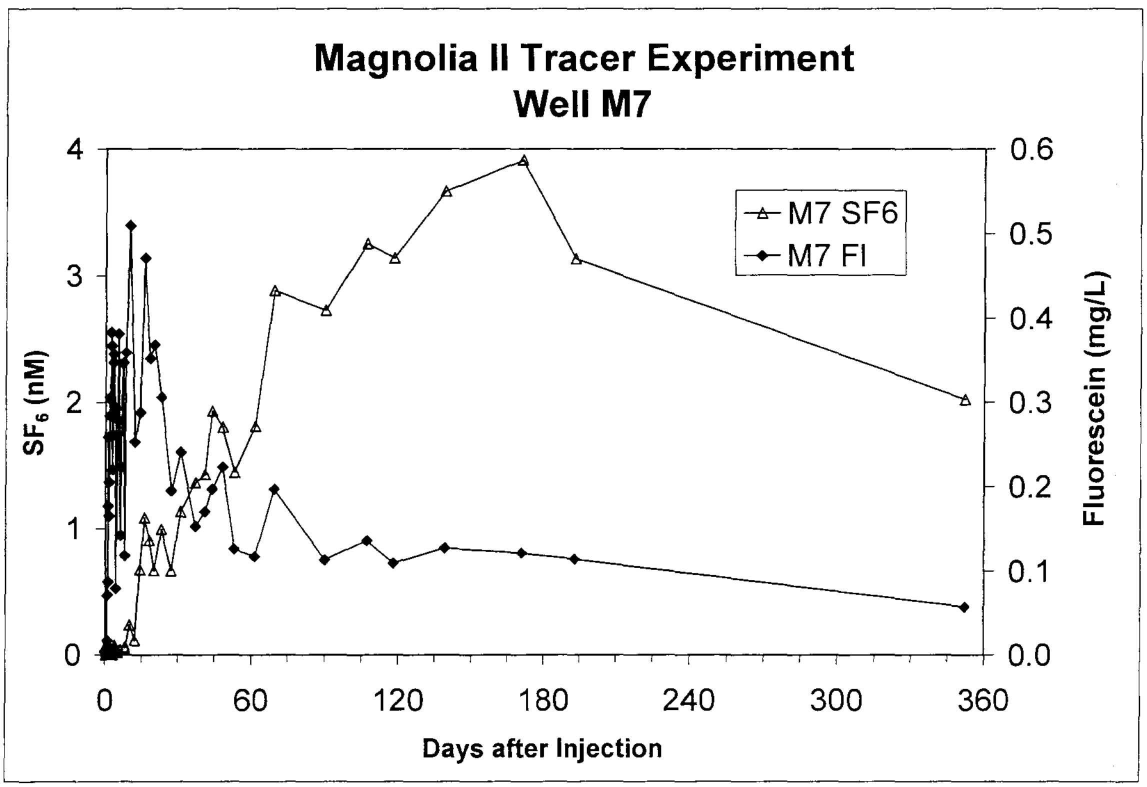

Figure 4- 12. Sulfur hexafluoride (open symbols) and fluorescein (closed symbols) data for well M7.

After the first observation of fluorescein, measurable concentrations were observed in all subsequent samples in every well, except in well M10, where it was detected only three times above the detection limit of 0.005 mg/L.

The SF_6 tracer behaved in a much different manner than the fluorescein tracer. In each well, the first sample taken after injection contained SF_6. Generally, the wells closest to the drainfield had higher concentrations than those further out towards the river (Figure 4- 13). SF_6 concentrations in these initial samples were highest in wells M1, M2, M5 and M6, indicating a likely pathway through the Karst. This initial SF6 peak may

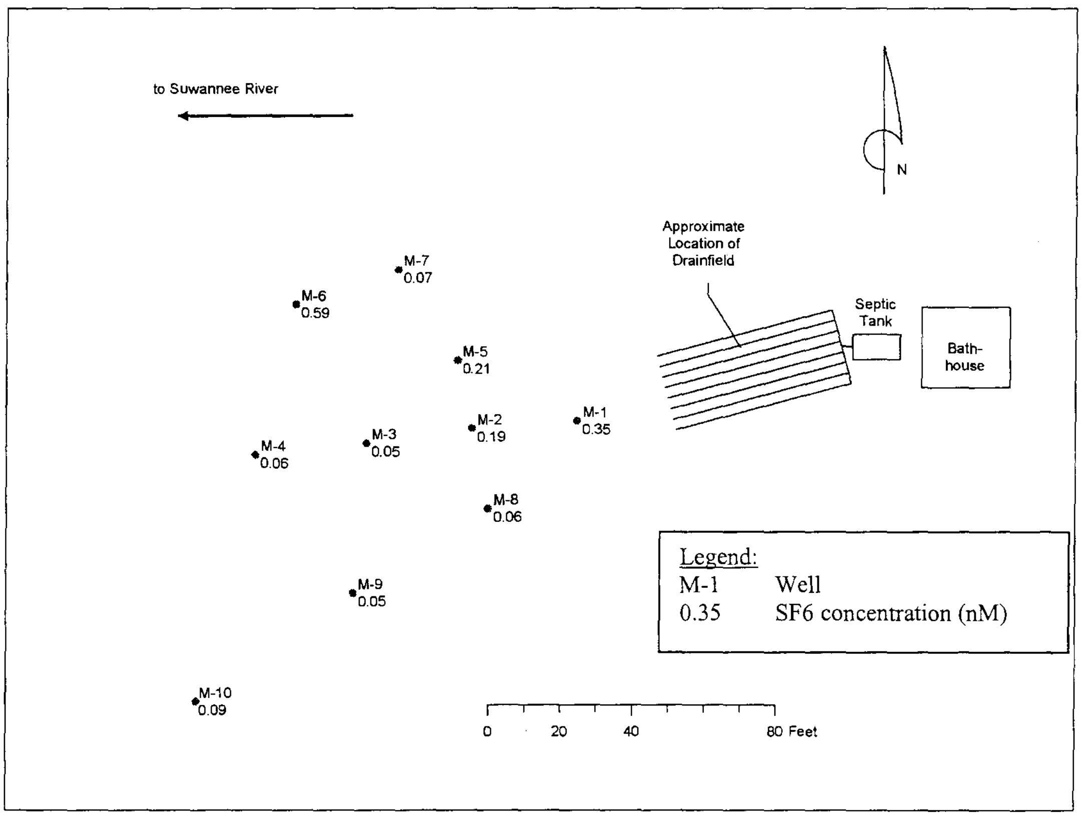

Figure 4- 13. Map with SF6 concentrations found in the initial sample after tracer injection (nM).

have been caused by an overloading of the septic system caused by the combination of full capacity loading on Memorial Day and the 50 gallon injection slug. After this initial observation, the SF_6 concentration decreased back towards the GC detection limits. After a period of time, the concentrations increased again, building up to an observed SF_6 peak. The SF_6 concentrations took much longer to rise to peak concentrations than the fluorescein. M2 was the first well to peak, with an observed SF_6 concentration of 16.13 nM occurring at 37.0 days (Figure 4- 7). On day 69 after injection, both M8 and M1 had observed SF_6 peaks (Figures 4-3 and 4-6). A SF_6 peak was observed at M3 on day 118 (Figure 4- 8), with peaks observed in all other wells occurring on day 171 (Figures 4- 4, 4- 5, 4-9 through 4-12). Wells M4 and M10 had significantly lower peak SF_6 concentrations (<0.80 nM) than all of the other wells (>3.9 nM), consistent with fluorescein observations.

Table 4- 1 summarizes times of first observations and times of peak for SF_6 and fluorescein concentrations. Transport velocities can be calculated from tracer data by several approaches. For the fluorescein data, the time of peak concentration was used to calculate velocities, not the time of initial tracer observation. The first observation of fluorescein occurred within 1.5 days in all wells except M1 (2.38 days). Fluorescein concentrations rose quickly to peak concentrations, indicating the fluorescein plume did not significantly disperse and the peak concentrations represent an average of tracer's arrival.

The initial observations of SF_6 were not used in velocity calculations because these observations occurred in all of the wells within 0.25 day. These initial observations may have been an artifact of the injection or they may have resulted from gaseous SF_6 flowing towards the wells through the air or the vadose zone. Velocities were calculated using both the start of the SF_6 peak and the peak in concentration. The start of the peak was considered to be the first observation of SF_6 over 0.100 nM after levels had returned to below detection limits from the higher initial levels detected within the first few hours following tracer injection. The start of the peak was used because the SF_6 peak rose very slowly, taking from 33 to 170 days from the start of the peak, indicating significant dispersal of the plume. Transport velocities were calculated from both the injection point to the wells and also between various wells.

Table 4- 1. Time following injection when tracers were first observed and when they reached their peak. First value in each column is time in days, second value (in parentheses) is the observed concentration of SF_6 (nM) and fluorescein (mg/L) in monitoring wells.

Well ID	Initial Fl	Peak Fl	Initial SF_6 Peak	2^{nd} SF_6 Peak Start	2^{nd} SF_6 Peak
M1	2.38 (0.013)	18.09 (1.449)	0.03 (0.345)	10.00 (0.243)	69.2 (12.537)
M2	1.49 (0.018)	22.94 (2.843)	0.05 (0.190)	3.88 (0.131)	37.0(16.126)
M3	1.41 (0.052)	4.09 (1.864)	0.20 (0.051)	10.03 (0.173)	118 (8.171
M4	1.42 (0.014)	8.28 (0.060)	0.21 (0.062)	41.04 (0.181)	171 (0.746)
M5	0.80 (0.158)	2.19 (1.313)	0.07 (0.208)	10.01 (0.169)	171 (8.738)
M6	0.95 (0.022)	3.16 (0.359)	0.19 (0.59)	14.24 (0.155)	171 (4.090)
M7	0.83 (0.017)	10.02 (0.509)	0.18 (0.066)	10.01 (0.236)	171 (3.912)
M8	0.66 (0.397)	1.13 (11.01)	0.06 (0.057)	3.87 (0.138)	69.2(16.994)
M9	0.88 (0.042)	1.80 (5.618)	0.22 (0.047)	8.03 (0.121)	171 (4.268)
M10	0.25 (0.008)	171 (0.010)	0.24 (0.086)	44.02 (0.133)	171 (0.271)

Magnolia Water Quality

Nutrient concentrations were characterized by average concentrations and their standard deviations. Nitrate-nitrogen and total phosphorus values less than the detection limits of 0.012 and 0.014 mg/L, respectively, were treated as zero for average calculations. In addition to average nutrient concentrations, the maximum values of tracer and nitrate-nitrogen concentrations are also listed in Table 4- 2. Detailed sampling results are given in Appendix 2.

Background well CA1, a deep well, had nitrate-nitrogen concentrations ranging from less than 0.012 to 0.147 mg/L with an average of 0.086 mg/L for the four samples above the detection limit of 0.012 mg/L. The five sample results available for the background well MB2 had nitrate-nitrogen levels ranging from 0.08 to 1.61 mg/L with average and standard deviation of 0.613 ± 0.741 mg/L.

Of the ten monitoring wells sampled for nutrients at the Magnolia site, all but M10 and M4 had elevated levels of nitrate-nitrogen compared to the background wells. In well M9, the nitrate-nitrogen concentrations were not greater than those of the background wells until the last three sampling events, when concentrations increased to 35.9 mg/L on May 10, 2004.

In wells M1 through M8 except M4, exceptionally high nitrate-nitrogen concentrations were measured on August 22, 2003. The following are the nitrate-nitrogen values for August 22, 2003 in descending order, M2 63.2 mg/L, M7 62.8 mg/L, M5 61.6 mg/L, M8 54.6 ± 14.7 (duplicate sample), M6 51.1 mg/L, M1 49.8 ± 18.8 (duplicate sample), M3 33.9 mg/L. The cause of this increase could not be determined, it occurred at a time when the groundwater level was relatively high and there were large differences between the results from a sample and its duplicate. The increase by a factor of two to three caused high standard deviations reported and shifted the average concentration values. The averages without the high values on August 22, 2003 were in descending order: M1 27.99 mg/L, M8 26.55 mg/L, M5 20.99 mg/L, 17.75 mg/L, M7 13.16 mg/L, M6 12.73 mg/L, M3 12.17 mg/L.

Total phosphorus was found to be elevated in all of the wells except M4, M9, and M10. The background level for total phosphorus at CA1 was 0.01 ± 0.014 mg/L, with three of five samples below the detection limit of 0.014 mg/l. At the background well

MB2 the average total phosphorus concentration was 0.187 mg/L. The highest average levels of total phosphorus at the Magnolia site were found in M8, 0.930 ± 0.235 mg/L, and in M2 at 0.761 ± 0.285 mg/L. In well M9, the total phosphorus concentrations did not increase in the last two sampling events, as did the nitrate-nitrogen concentrations.

Table 4- 2. Summary of water quality monitoring results at the Magnolia II site and background wells. Average total phosphorus and nitrate-nitrogen concentrations are listed together with the highest tracer and nitrate-nitrogen measurements.

Well ID	Average ± Standard DeviationTotal P (mg/L)	High NO_3-N (mg/L)	Average ± Standard DeviationNO_3-N (mg/L)	High SF_6 (nM)	High Fl (mg/L)
CA1	0.010 ± 0.014	0.147	0.069 ± 0.062	-	-
MB2	0.187 ± 0.174	1.61	0.613 ± 0.741	-	-
M1	0.345 ± 0.119	49.8 ± 18.8	29.45 ± 9.76	12.54	1.45
M2	0.761 ± 0.285	63.2	22.80 ± 17.50	16.13	2.84
M3	0.541 ± 0.119	33.9	14.89 ± 11.16	8.17	1.86
M4	0.123 ± 0.266	0.774	0.25 ± 0.23	0.75	0.06
M5	0.239 ± 0.391	62.6	26.07 ± 15.23	8.74	1.31
M6	0.129 ± 0.318	51.4	17.53 ± 14.47	4.09	0.36
M7	0.345 ± 0.401	63.3	19.37 ± 17.74	3.91	0.51
M8	0.930 ± 0.235	54.6 ± 14.7	30.06 ± 17.10	16.99	11.01
M9	0.034 ± 0.064	35.9	6.89 ± 12.58	4.27	5.62
M10	0.038 ± 0.016	0.146	0.03 ± 0.05	0.27	0.01

Fecal coliform bacteria were not consistently present in any of the wells, but were found sporadically in several wells. In the two background wells, fecal coliform were never above the detection limit of 2 CFU/100 mL. The highest number of fecal coliform, 932 CFU/100mL, was found in well M8 on May 20, 2003. This was the same sampling event that yielded the lowest nitrate-nitrogen concentration observed in well M8, 5.9 mg/L. The next largest concentration of fecal coliforms was 159 CFU/100mL observed in M5 on December 3, 2003. The only other sample with more than 100 CFU/100mL (114 CFU/100mL) was taken from M6 on August 22, 2003 the same day that the highest nitrate-nitrogen concentrations were found in this well. In well M2, 82 CFU/100mL were detected on January 26, 2004 and 41 CFU/100mL on July 7, 2003. In well M7, 54 CFU/100mL were detected on August 22, 2003 and in M9, 61 CFU/100mL were in the sample on July 07, 2003. No other samples contained more than 40 CFU/100mL, although there were a few samples in various wells over the detection limit of 2 CFU/100mL. The complete fecal coliform and nutrient data are found in Appendix 2.

During the April 1, 2003 sampling event, the river was several feet above normal and only wells M1 and M2 were above water. The nutrient levels and fecal coliform numbers measured on this date were in the mid-range for the respective parameters measured in each well over the course of the experiment. A surface water sample from the floodwaters was taken two to three feet towards the river from M2. Most of the total nitrogen in this sample, 2.46 mg/L of 3.24 mg/L, was in the form of TKN, with 0.781 mg/L nitrate-nitrogen and 0.161 mg/L ammonia-nitrogen. The total phosphorus concentration of 0.061 mg/L in the surface water sample was not above those found in the background wells. The fecal coliform count of 98 CFU/100 mL was elevated compared to 2 or less colonies found in both samples in well M2 on the same date.

Sulfur Hexafluoride and Fluorescein Tracer Experiment at Hickory

The drainfield of the Hickory campground bathhouse was injected with the solution of SF_6 and fluorescein on July 4, 2003. The injection was started at 02:16 p.m. and ended at 02:36 p.m. and the additional injection of 18-20 gallons of tap water used to rinse the container and flush the last of the tracer into the system was completed at 02:48 p.m.. The midway point of the entire process, 02:32 p.m., was chosen as the starting time for the tracer injection in all calculations.

SF_6 concentrations were detected in the first few hours after injection in all of the wells, Catfish Hotel, Sue Sink and Manatee Springs. The higher concentrations were closer to the drainfield lines and concentrations generally decreased with distance from the drainfield lines (Figure 4- 14). The highest concentrations were found in wells S1, located in a possible solution pipe in the center of the drainfield, and S2, located at the end of a drainfield line. The next highest concentrations were in wells C5 and C6, both located near drainfield lines. It is highly unlikely that contamination was an issue, as one would expect the distribution of concentrations in the well field to be random in this case.

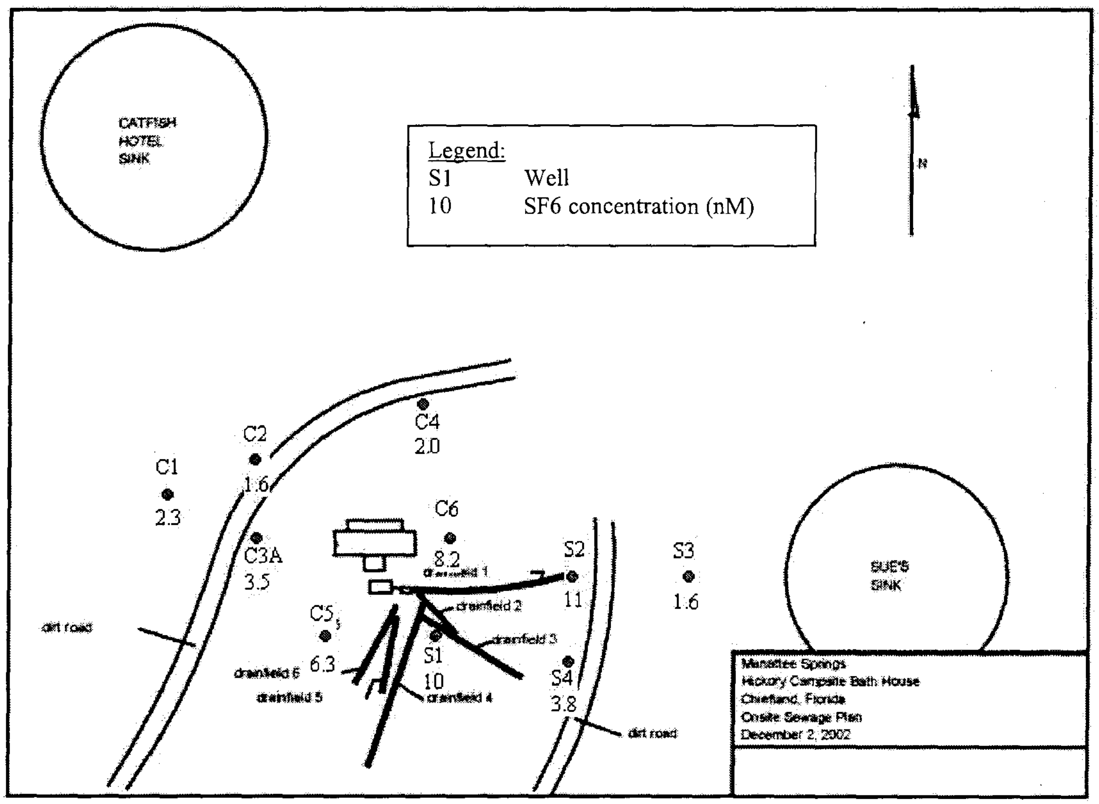

Figure 4- 14. Map of SF6 concentrations in the initial sample after tracer injection.

The initial sample after tracer injection contained the highest SF_6 concentration measured in the two sinks, the spring and all of the wells, respectively, with the exception of well S1. Complete tracer data are presented in Appendix 1. Well S1, which was installed into a GPR-anomaly, showed a double-peak pattern for SF_6 and a single peak for fluorescein. After the initial observation of SF_6 in well S1 at 10.38 nM, the concentration dropped below 1 nM within 3.5 hours. Concentrations stayed below 1nM for the next seven days. Concentrations increased then again, and at 17.10 days after injection a concentration of 10.78 nM was observed. Concentrations stayed above 10 nM through the sample on day 76.98. On day 97.94, the concentration was observed to have decreased to 4.99 nM and further decreased to 1.14 nM on day 151.9 and 0.26 nM 311.0 days after injection (Figure 4- 15).

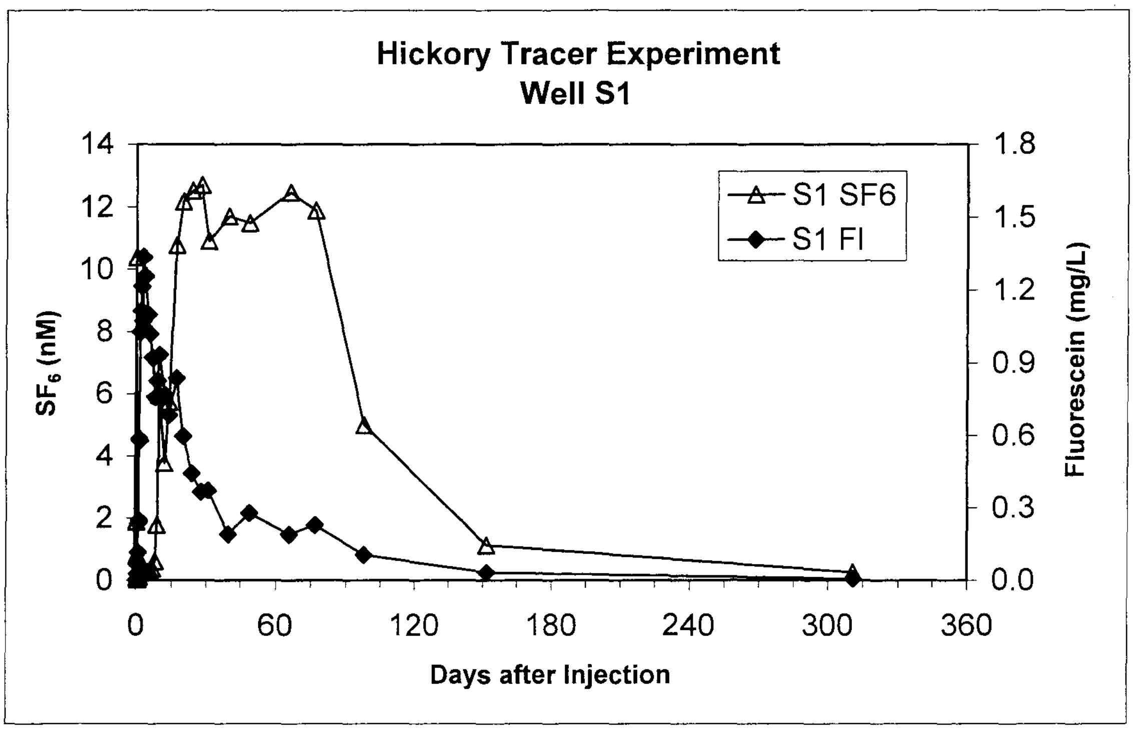

Figure 4- 15. Sulfur hexafluoride (open symbols) and fluorescein (closed symbols) data for well S1.

Well S1 had the highest concentrations of fluorescein observed in the Hickory campground experiment. At 0.42 days, 0.027 mg/L of fluorescein was observed and concentrations increased to an observed concentration peak of 1.34 mg/L at 2.8 days. After this peak concentration, fluorescein concentrations decreased but were well above detection limits through the sampling event at 151.9 days. The next sample, taken at 310.9 days, had a fluorescein concentration of 0.006 mg/L, just barely above the detection limit (Figure 4- 15).

A different pattern was observed in wells S2, S3, S4, C1, C2, C3 and C4 (Figures 4- 16 through 4- 22). It consisted of a high initial SF_6 observation, followed by a decrease to below 1 nM within a few hours, then a much smaller secondary peak of less than 1 nM with concentrations decreasing after the secondary peak for the remainder of the experiment These wells also showed low observed fluorescein concentrations.

Well S2, located at the end of a drainfield trench, showed the highest concentration of SF_6 (11.43 nM) in the first round of sampling within one hour after tracer injection. At 0.45 day after injection, the concentration was below 1nM and stayed below 1nM for the duration of the experiment. A secondary peak of 0.79 nM was observed at 1.20 days after injection. Fluorescein (0.009 mg/L) was observed only once, at 0.62 day, above background fluorescence. (Figure 4- 16).

At wells S3, S4 and C4, the highest concentrations of SF_6, (1.55 nM, 3.82 nM, 1.99 nM) were observed within two hours of injection. After SF_6 concentrations decreased, second SF_6 peaks of 0.71 nM at 0.41 day in C4 and 0.51 and 0.53 nM, respectively, at 1.2 days in S3 and S4 were observed. Fluorescein (0.02, 0.008 and 0.012 mg/L, respectively) was observed once above the background fluorescence of 0.005 mg/L, also at 1.2 days (Figure 4- 17, 4- 18, 4- 22). At wells C1, C2 and C3, fluorescein concentrations never exceeded 0.005 mg/L (Figures 4- 19 through 4- 21).

In wells C5 and C6, a somewhat similar pattern was observed, except that the SF_6 concentrations did not decrease to the same extent after the second peak and a third peak was observed much later in the experiment (Figures 4- 23 and 4- 24). Fluorescein was observed multiple times in these wells. In well C5, 6.26 nM of SF_6 was measured in the first sample taken less than two hours after injection. After a decrease in concentration, a second peak of 0.83 nM was observed at 0.34 day. Concentrations of SF_6 decreased again until 13.98 days when the SF_6 concentrations were observed to increase again with a third peak of 1.11 nM being observed on day 77.04. Fluorescein (0.018 mg/L) was first detected at 1.78 days. Fluorescein was not detected again until 27.95 days (0.054 mg/L) and a concentration peak of 0.073 mg/L was observed at 39.88 days after injection. Fluorescein was not detected after 66.02 days in well C5. (Figure 4- 23)

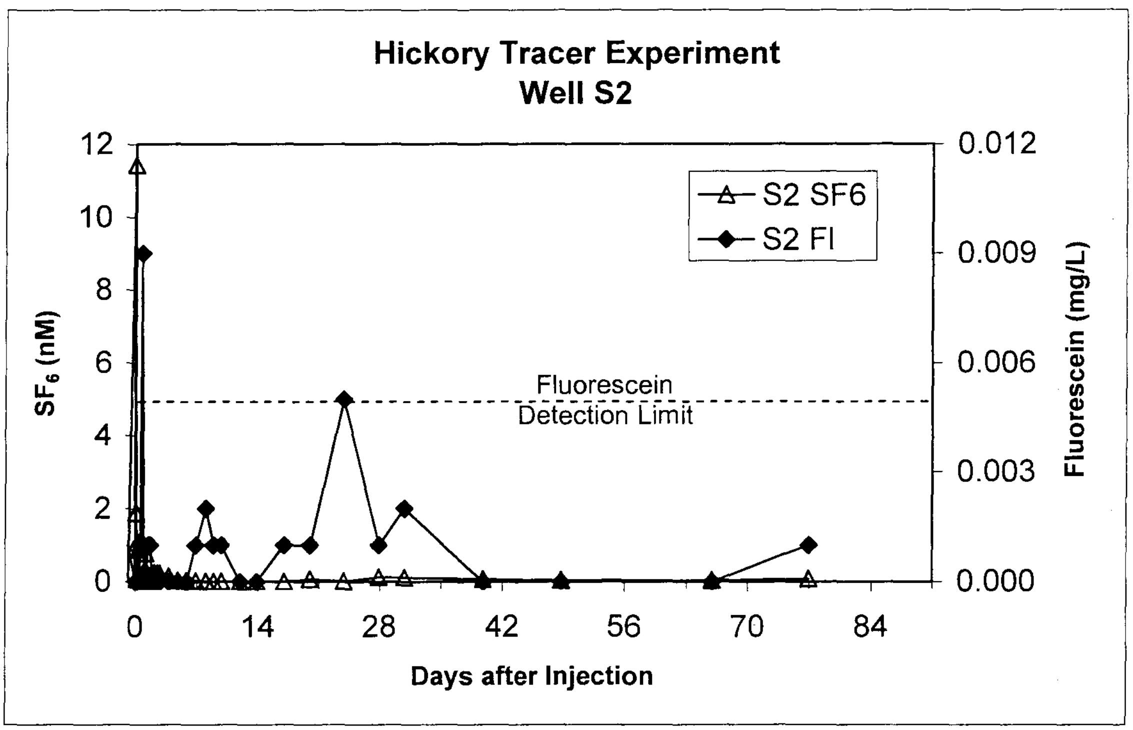

Figure 4- 16. Sulfur hexafluoride (open symbols) and fluorescein (closed symbols) data for well S2.

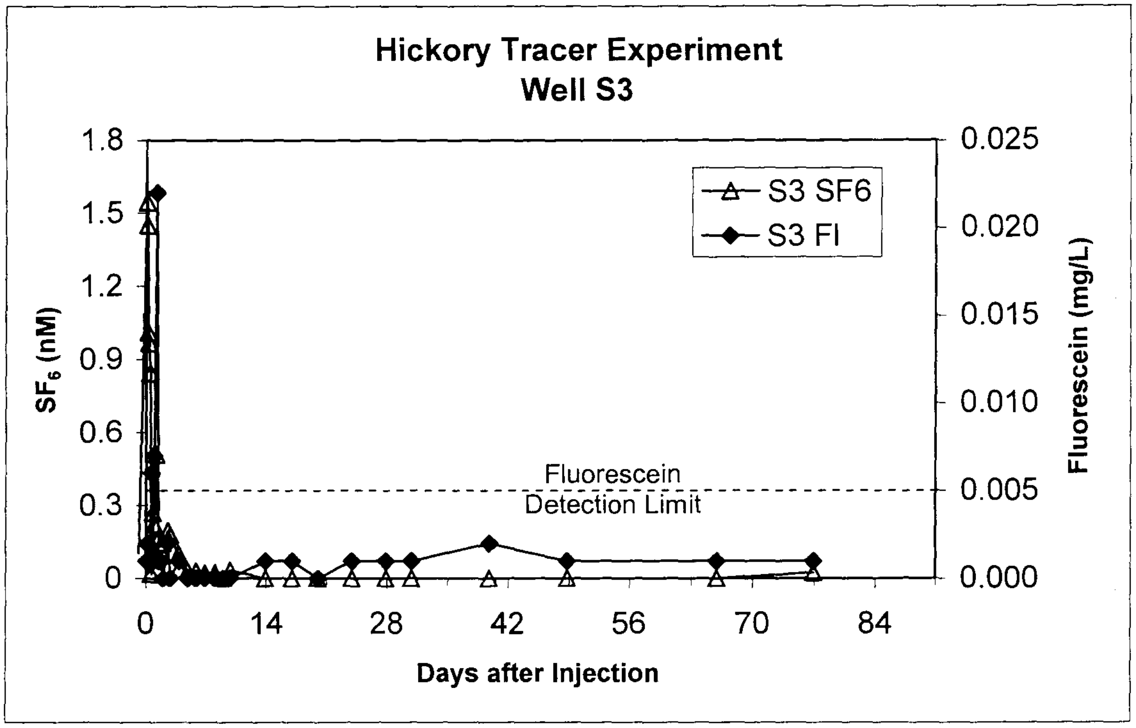

Figure 4- 17. Sulfur hexafluoride (open symbols) and fluorescein (closed symbols) data for well S3.

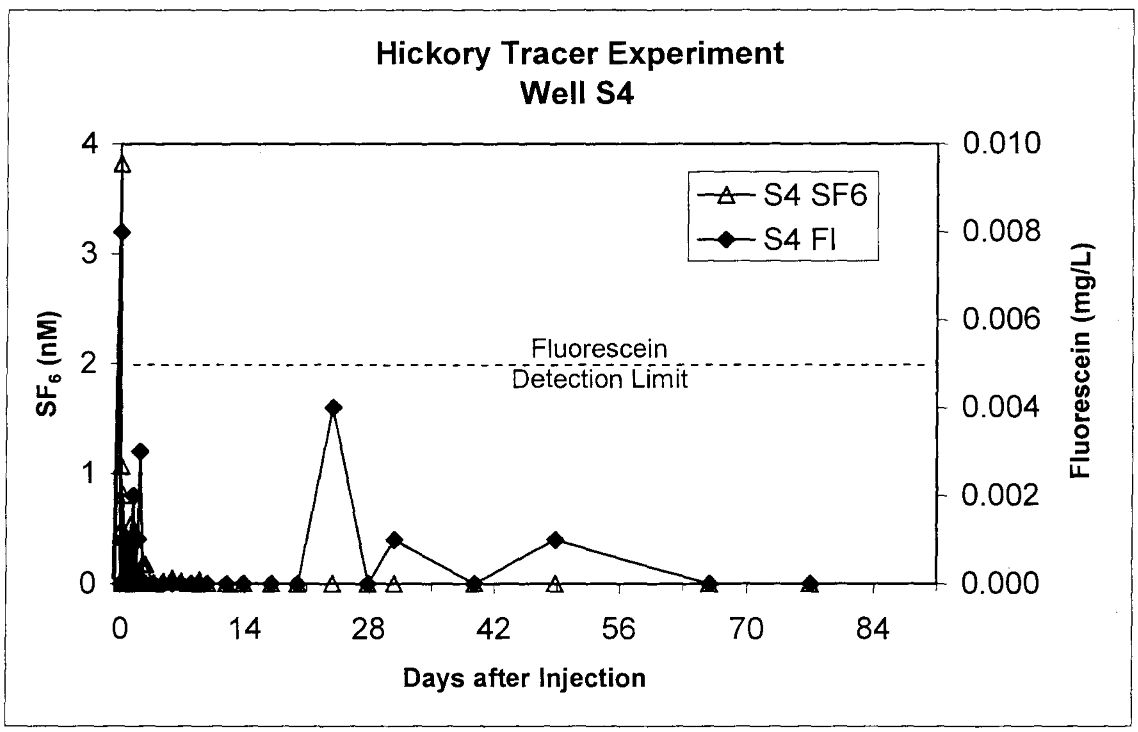

Figure 4- 18. Sulfur hexafluoride (open symbols) and fluorescein (closed symbols) data for well S4.

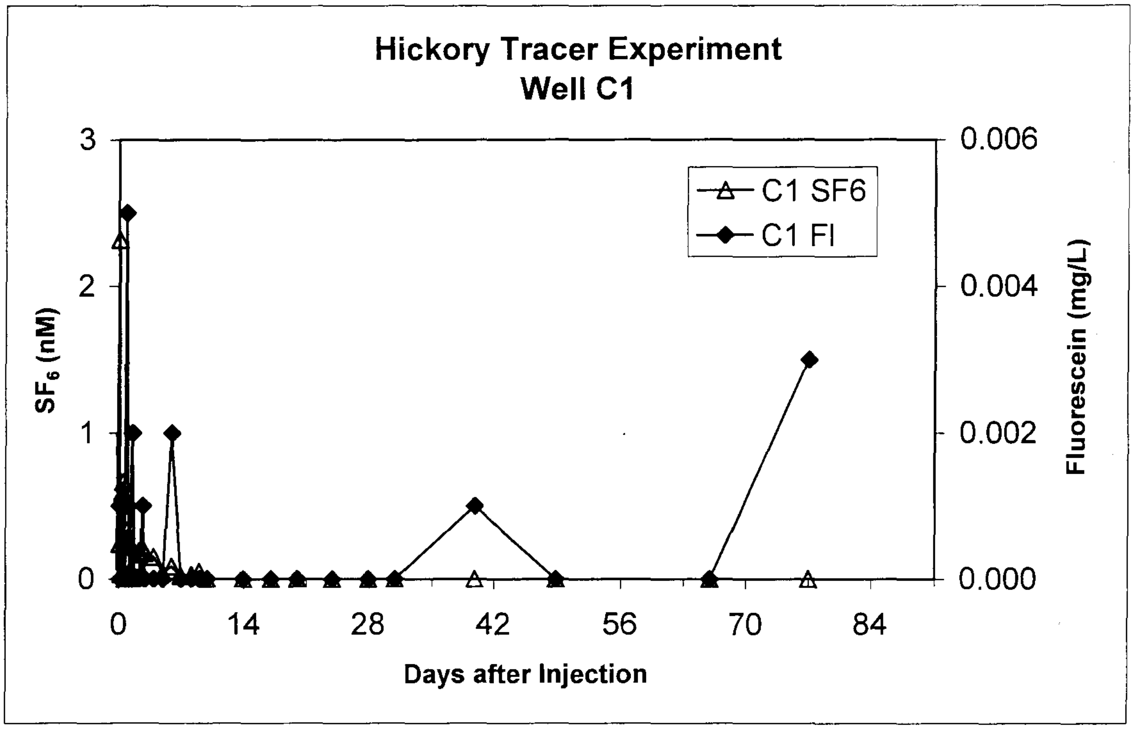

Figure 4- 19. Sulfur hexafluoride (open symbols) and fluorescein (closed symbols) data for well C1.

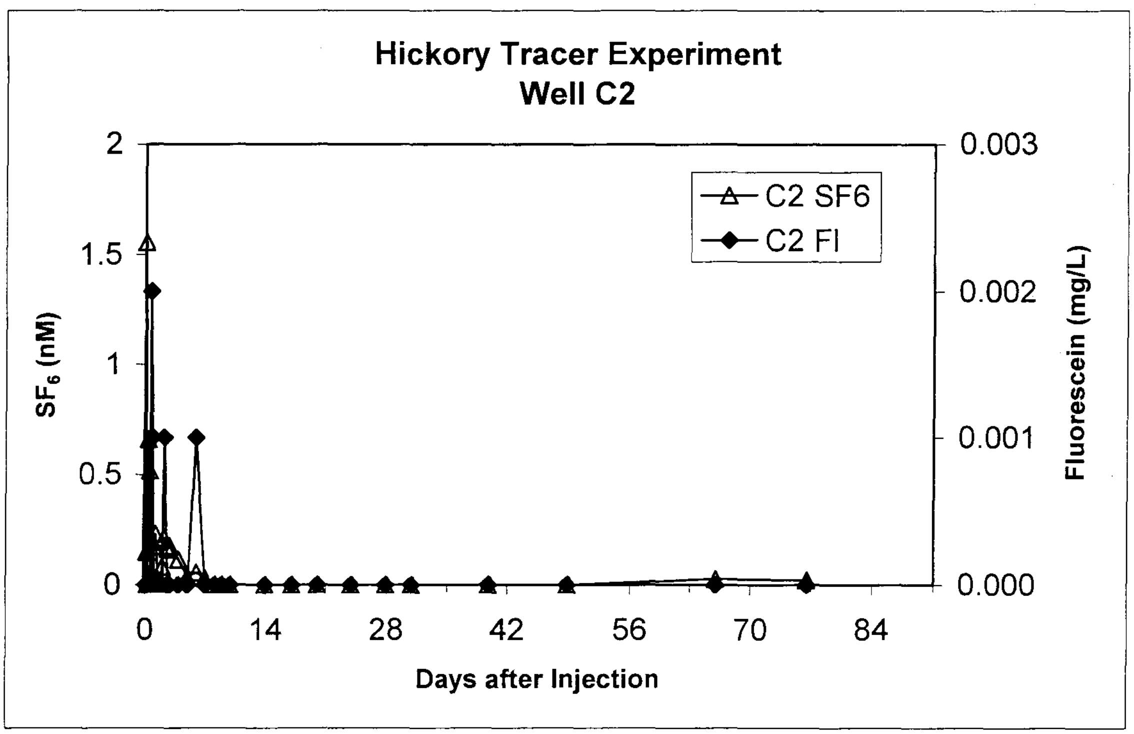

Figure 4- 20. Sulfur hexafluoride (open symbols) and fluorescein (closed symbols) data for well C2.

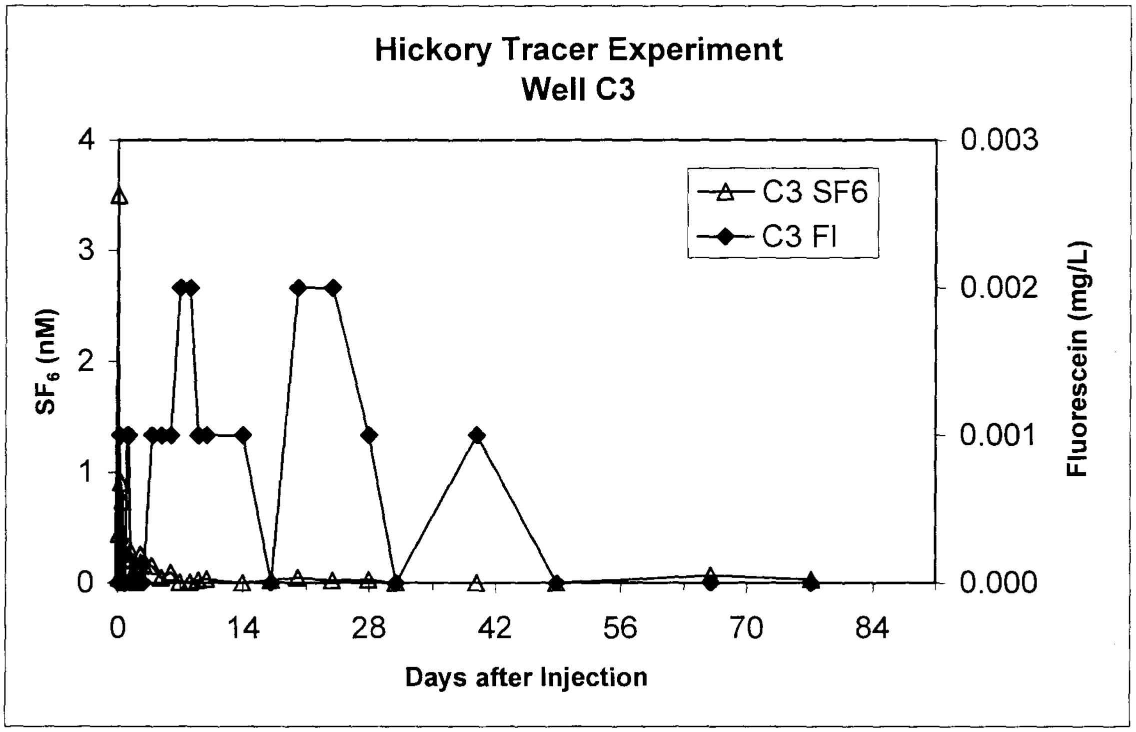

Figure 4- 21. Sulfur hexafluoride (open symbols) and fluorescein (closed symbols) data for well C3.

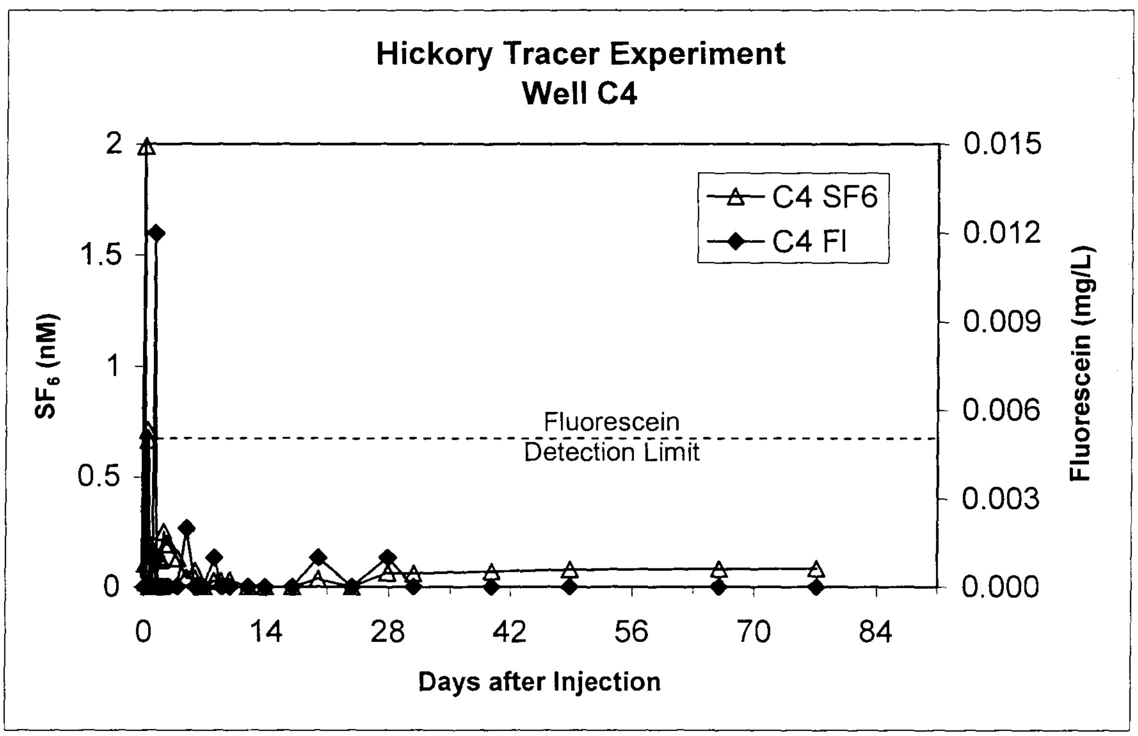

Figure 4- 22. Sulfur hexafluoride (open symbols) and fluorescein (closed symbols) data for well C4.

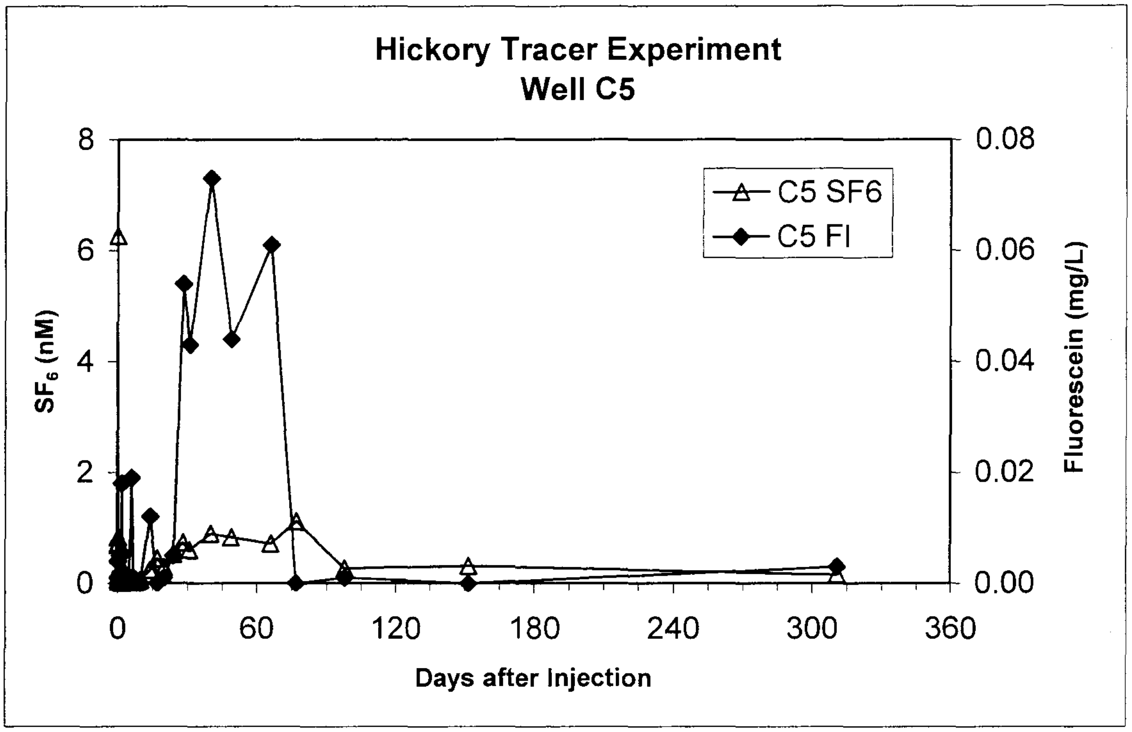

Figure 4- 23. Sulfur hexafluoride (open symbols) and fluorescein (closed symbols) data for well C5.

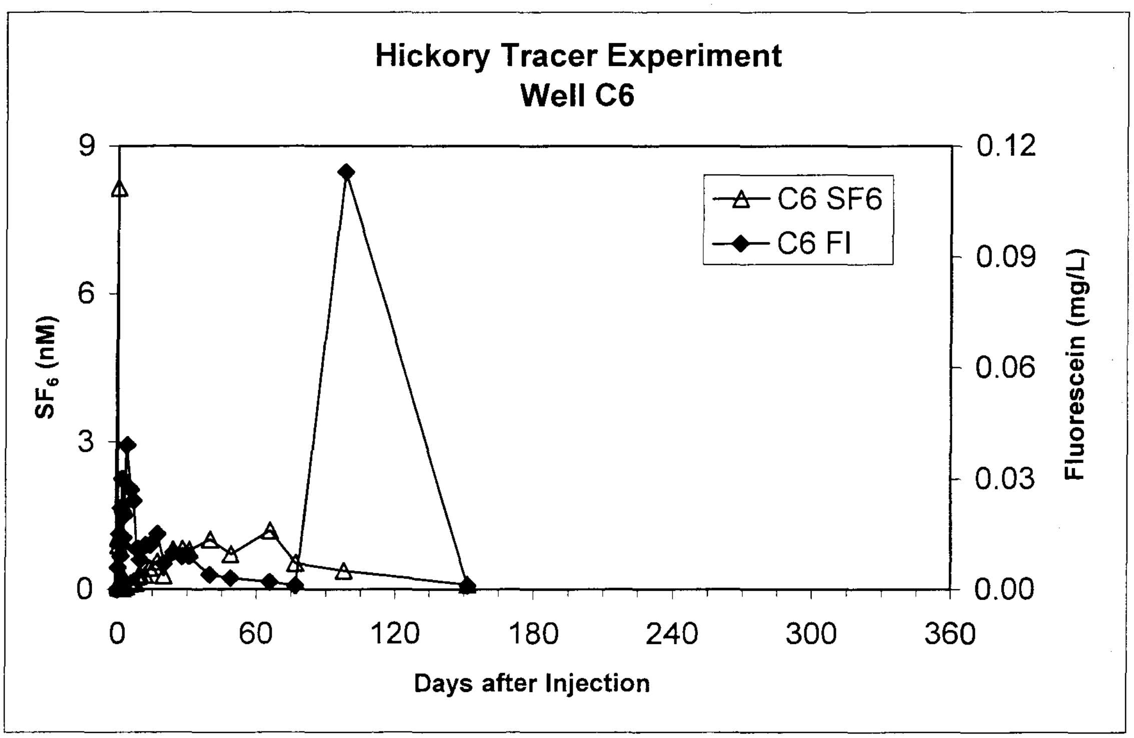

Figure 4- 24. Sulfur hexafluoride (open symbols) and fluorescein (closed symbols) data for well C6.

In well C6, an initial SF_6 concentration of 8.15 nM was observed within two hours of injection, after concentrations decreased, a second SF_6 peak of 0.83 nM was observed at 0.34 days. Concentrations again decreased intermittently and a third SF_6 peak (1.11 nM) was observed at 66 days. Fluorescein (0.006 mg/L) was first detected at 0.28 day and a peak concentration of 0.039 mg/L was observed at 3.8 days. After concentrations had fallen to below background fluorescence, the highest fluorescein concentration for this well of 0.11 mg/L was observed on day 98.0, which coincided with the highest nitrate-nitrogen (22.9 mg/L) observation at this well. (Figure 4- 24)

Due to logistics, the two sinkholes and the spring were not sampled as frequently as the monitoring wells. Sue Sink was sampled within four hours, 0.15 day, after injection and 0.98 nM of SF_6 was measured. Samples were taken only for the first five days at Sue Sink and smaller SF_6 concentrations were observed in these samples. Catfish Hotel also was sampled within four hours and a peak concentration of 0.77 nM was observed. A second SF_6 peak of 0.30 nM was observed at 1.81 days. Concentrations then decreased until they were below detection limits eight days after injection. The spring itself was sampled 4.5 hours or 0.19 day after the injection and a SF_6 concentration of 0.514 nM was observed. A second peak of 0.49 nM was observed at 1.84 days. Concentrations decreased again, and the last sample with SF_6 above the detection limit was obtained eight days after injection. Cave divers took samples at approximately 1.9 days after injection within the cave up current from Catfish Hotel. All six of these cave samples contained SF_6 with concentration ranging from 0.13 to 0.31 nM and averaging 0.207 ± 0.078 nM.

Small concentrations of fluorescein were observed in Catfish Hotel, 0.017 mg/L, and the spring, 0.008 mg/L, both at 20.05 days after injection (Figure 4- 26). Fluorescein was not observed in either Sue Sink or inside the cave system. However, it should be considered that the cave was only sampled on one day and Sue Sink was only sampled for the first five days of the experiment.

Hickory Water Quality

Of the ten wells sampled for nutrients at Hickory campground, only S1, C5 and C6 had elevated levels of nitrate-nitrogen compared to the background wells. Background well CA1 had nitrate-nitrogen concentrations ranging from less than 0.012 to 0.147 mg/L with an average of 0.086 ± 0.056 mg/L for the four samples above the detection limit of 0.012 mg/L. MB2, the shallower background well, had nitrate-nitrogen levels ranging from 0.08 to 1.61 mg/L with an average of 0.613 ± 0.741 mg/mL for five samples.

Well S1 had nitrate-nitrogen concentrations ranging from 4.28 ± 0.02 mg/L to 56.1 mg/L with an average of 21.89 ± 16.08 mg/L for nine samples. Well C5 had the next highest average nitrate-nitrogen concentration at 11.70 ± 14.71 mg/L for nine samples and a range of 1.85 mg/L to 41.3 mg/L. The highest concentration found in both C5 and S1 occurred on August 22, 2003. For the first 5 sampling events for well C6 the nitrate-nitrogen concentrations averaged 1.43 ± 0.33 n=5. On October 10, 2003 nitrate-nitrogen was measured to be 22.9 mg/L and on December 12, 2003 the concentration of nitrate-nitrogen was observed to be 5.21 mg/L. The average nitrate-nitrogen concentration of the seven samples taken during the course of the study was 5.04 ± 8.01 mg/L.

The background level for total phosphorus at CA1 was 0.01 ± 0.014 mg/L, with three of five samples below the detection limit of 0.014 mg/l. At the background well MB2 the average total phosphorus concentration was 0.187 mg/L.

Well S1 was the only well at the Hickory site to consistently contain total phosphorus concentrations above those measured in the background wells. In every sample the total phosphorus concentration was higher than background with a high of 4.890 mg/L measured on February 19, 2003 and a low of 0.388 measured on January 26, 2003.

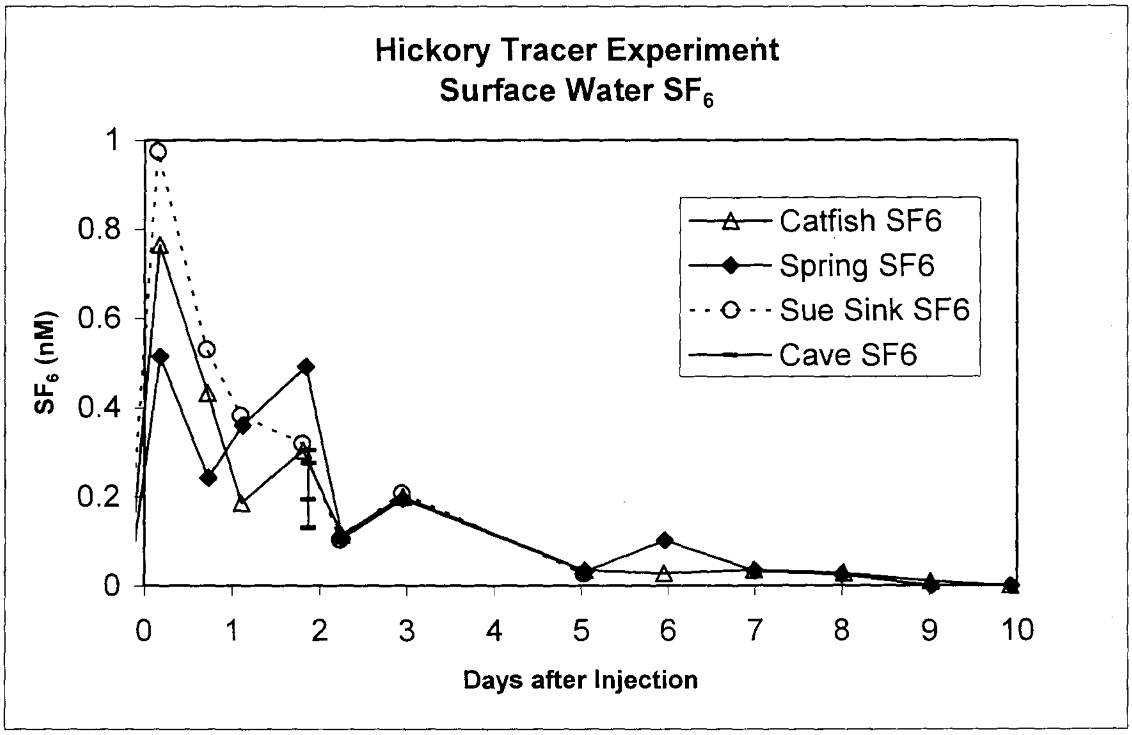

Figure 4- 25. Sulfur hexafluoride data for surface water body and cave samples.

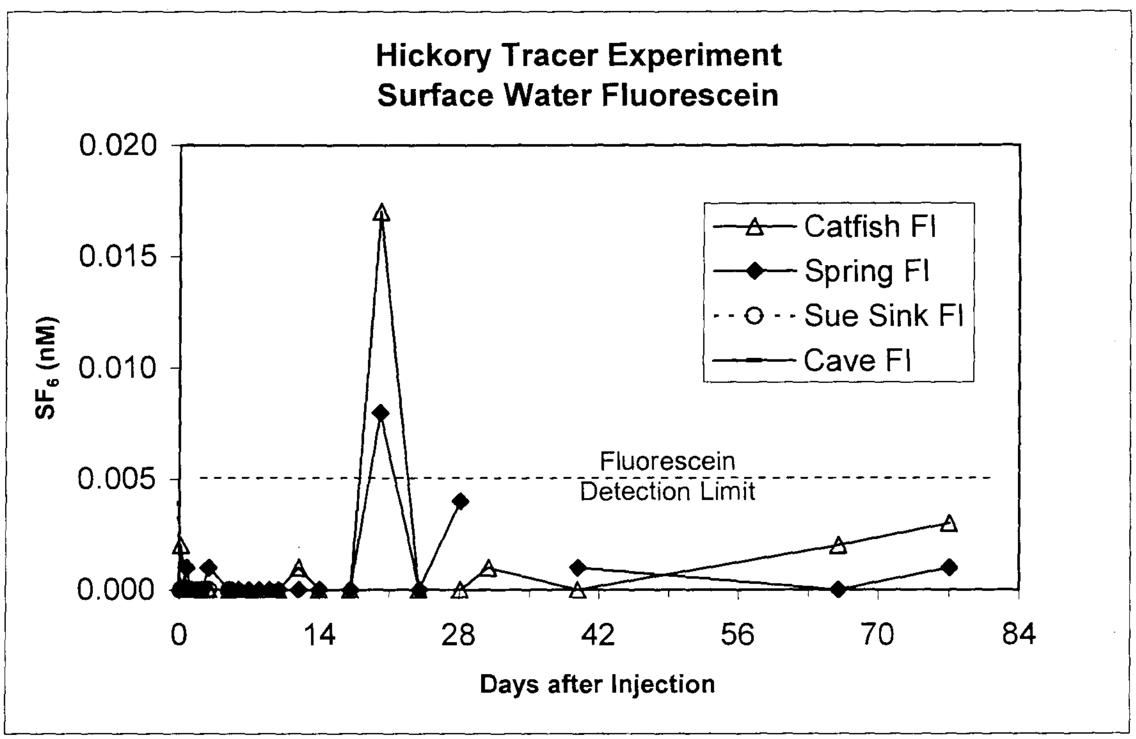

Figure 4- 26. Fluorescein data for surface water body and cave samples.

Except for well S1, the total phosphorus concentrations in the Hickory well field were very low and in many cases below the concentrations found in the two background wells. In five sampling events, well C1 had only one sample above detection limits, 0.032 mg/L and its duplicate was below detection limit of 0.014 mg/L. In well C2, all five samples were below the detection limit. In wells C3, C4, C6, and S2 no sample was above 0.05 mg/L, and there were samples in each well that were below the detection limit. In well C5, the total phosphorus in the first three samples averaged 0.152 ± 0.018 and concentrations were below the detection limit in the following six sampling events. Well S3 had total phosphorus concentrations ranging from below the detection level on July 7, 2003 to 0.703 mg/L observed on February 19, 2003. In well S4, the total phosphorus cocentrations ranged from below the detection limit to 0.260 mg/L.

Surface water samples were taken on April 4, 2003 from Sue Sink, Catfish Hotel, the spring, and an unnamed sink north of Catfish Hotel and in the proximity of Hickory campground. The spring and river levels were several feet above normal levels. Nitrate-nitrogen concentrations in these surface water were elevated compared to background well concentrations: spring at 2.09 mg/L, Catfish Hotel at 2.07 mg/L, Sue Sink at 1.7 mg/L, the unnamed sink at 0.261 mg/L and below the detection limit (duplicate). The unnamed sink had 0.27 ± 0.028 mg/L total phosphorus and the other three bodies of water had levels below the detection limit. The unnamed sink had 194 and 274 CFU/100 mL, while lower numbers where found in the spring (12 CFU/100mL), Catfish Hotel (19 CFU/100mL) and Sue Sink (17 CFU/100mL).

The Hickory campground was closed for renovations on September 4, 2003, 62 days after injection. After the September 19, 2003 sampling event, only wells S1, C5 and C6 were sampled. C6 was last sampled on December 03, 2003 or 152 days after injection. At some time between then and January 26, 2004, well C6 was damaged by construction activity preventing further sampling. Hickory campground reopened on May 3, 2004.

Discussion

Magnolia Tracer Experiment

The results of the tracer experiment at the Magnolia II campground illustrate the complexity of the subsurface flow in a karst environment. Groundwater can flow through conduits in the karst as conduit flow or as matrix flow through the pores of the rock matrix. The two tracers used in this study had very different characteristics, one was an inert gas, the other a fluorescent dye, and thus can be used to describe different aspects of the groundwater flow. Fluorescein is known to bind to carbonate material and therefore may not be suitable for describing matrix flow, but is useful in describing bulk flow. Sulfur hexafluoride will come out of solution into the gas phase in systems exposed to the atmosphere, such as may occur during conduit flow through a partially filled conduit or as the injection slug flows through the vadose zone. Therefore, SF_6 may not be suitable for tracing the part of the septic effluent that does not quickly enter the groundwater or flows on the very top of the groundwater.

The puddle that appeared in front of well M8 early in the experiment acted as another injection point for fluorescein, but not for SF_6. The correlation between peak SF_6 concentration and peak fluorescein concentration becomes much tighter when wells M8 and M9 are excluded (Figure 4- 27). This indicates that the SF_6 was reduced when the injection puddle seeped back into the groundwater. The SF_6 is thought to have degassed as the injection slug was puddled on the ground and while it flowed through the vadose zone towards where it appeared near well M8.

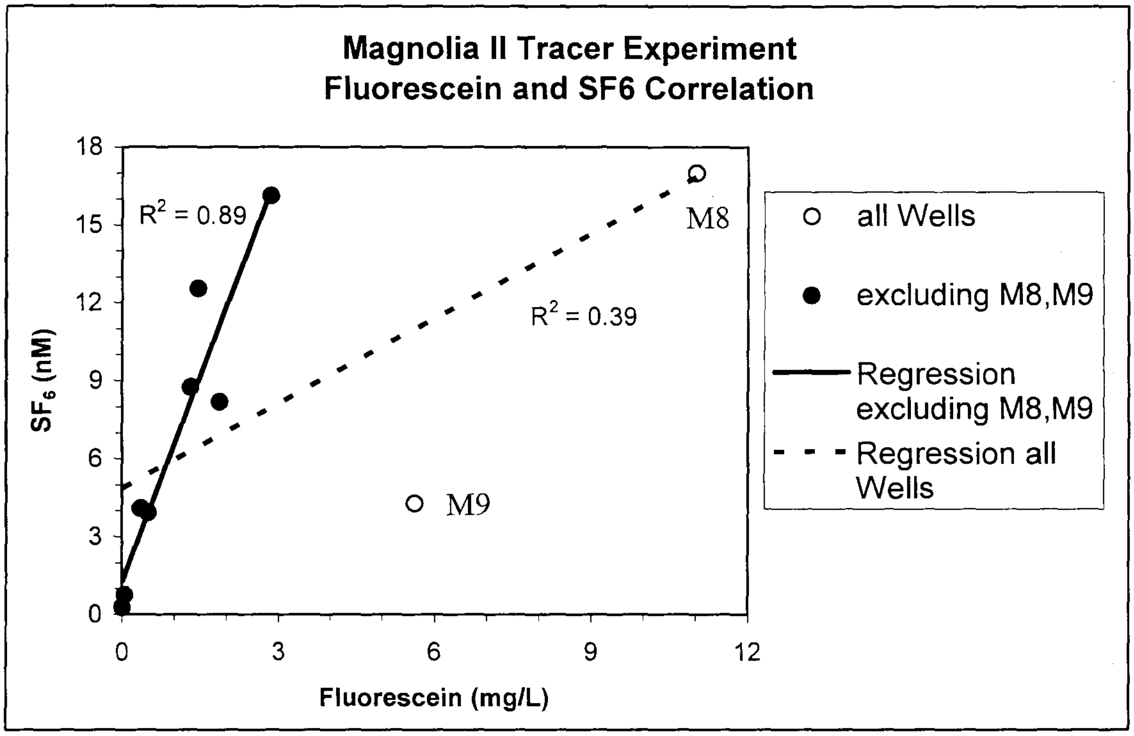

Figure 4- 27. Plot of highest measured SF_6 concentration against the highest measured fluorescein concentration in the wells at Magnolia II.

Overall, the tracer data confirmed that transport occurred from the drainfield towards the river. Velocities calculated from the injection point to the various wells using the tracer data illustrate these findings and are shown in Table 4- 3. The fluorescein data indicated that septic effluent did not flow fastest straight out of the mounded drainfield towards the river, but rather the fastest flow was towards the south side of the well field, then the next fastest was towards the north side of the well field.

On the south side of the well field, the velocity estimate based on peak fluorescein concentration from the injection point to M8 was 95 feet/day and from the injection point to M9 was 84 feet/day. On the north side, the flow rate from the injection point to M5 was 49 feet/day and from the injection point to M6 was 48 feet/day. In the center of the well field, the velocities from the injection point to M1, M2, and M3 were 4, 5 and 33 feet/day, respectively. The fluorescein that flowed to M3 most likely came from the south side of the well field as the fluorescein peak in M3 appeared before the peaks in M1 and M2 (Table 4-1). The well to well velocities showed the same distribution of velocities, with the highest velocity being 66 feet/day from M8 to M9, 48 feet/day from M5 to M6 was 48 feet/day and only 6 feet/day from M1 to M2 (Table 4- 3).

Table 4- 3. Velocities, in feet per day, calculated from the initial rises and peaks of tracer measurements at Magnolia II. The injection point (Inj.) was just upstream of the distribution box of the drainfield. (n/c = not calculated)

Well ID	Fl Initial Rise	Fl Peak	2nd SF_6 Initial Rise	2nd SF_6 Peak
Inj. To M1	31.58	4.16	7.52	1.09
Inj. To M2	70.97	4.61	27.26	2.86
Inj. To M3	95.57	32.95	13.43	1.14
Inj. To M4	116.26	19.94	4.02	0.97
Inj. To M5	133.44	48.74	10.66	0.62
Inj. To M6	159.65	48.00	10.65	0.89
Inj. To M7	150.20	12.44	12.45	0.73
Inj. To M8	162.88	95.13	27.78	1.55
Inj. To M9	172.06	84.12	18.86	0.89
Inj. To M10	1.20	1.20	4.65	1.20
M8 to M3	51.07	12.94	6.22	0.78
M8 to M9	201.36	66.12	10.65	0.44
M2 to M3	n/c	n/c	4.81	0.37
M3 to M4	3150	7.52	1.02	0.59
M5 to M6	311.6	48.20	11.06	n/c
M5 to M7	1006.7	3.86	n/c	n/c

The SF_6 velocity estimates based on the initial rise before the second peak indicated a slightly different pattern than the fluorescein data. The velocities on the south side of the well field were similar to the ones in the center of the well field, with slower velocities on the north side of the well field. The velocity from the injection point to M8 was 28 feet/day and from the injection point to M9 was 19 feet/day. This is only slightly faster than from the injection point to M2, 27 feet/day, and from the injection point to M3 at 13 feet/day. A slower velocity of 11 feet/day was calculated between the injection point to well M5 and from the injection point to M6. The well to well flow rates indicated that the effluent moves slower in the center of the well field than on either side. From M8 to M9 and from M5 to M6 a velocity of 11 feet/day was calculated, while from M2 to M3 a rate of 5 feet/day was calculated. The relatively low velocity determined from the injection point to well M1, 8 feet/day, may be related to the fact that it and well M4 were screened eight to ten feet deeper than the other wells. Only wells M4 and M10 had slower rates from the injection point at 4 feet/day and 5 feet/day respectively (Table 4- 3).

Magnolia Nutrient and Tracer Data Comparisons

The wells with the highest nitrate-nitrogen and total phosphate concentrations also had the highest tracer concentrations as shown previously in Table 4- 2. The peak tracer data correlated well with the average nutrient data, strongly indicating that the nutrients found in the well field are in fact from the septic system. Figures 4-28 and 29 show the tracer concentrations vs. average nutrient concentrations. The correlation coefficients between the fluorescein data and the nitrate-nitrogen and total phosphorus data increased when wells M8 and M9 were excluded from the regression analysis. This exclusion slightly decreased the correlation for SF_6. This difference may indicate that the puddle of effluent observed in front of well M8 on the day of injection acted as a second injection point into the groundwater for Fluorescein, but not for SF_6.

Well M8 had the highest concentrations of average nitrate-nitrogen, average total phosphorus, fecal coliform sample, fluorescein and SF_6 concentrations. Wells M4 and M10 had nitrate-nitrogen and total phosphorus concentrations similar in magnitude to those found in the background wells and the lowest concentrations of both tracers. The other seven wells contained significant amounts of both tracers as well as nutrient levels well above background levels.

Magnolia II Average Nitrate vs Tracers

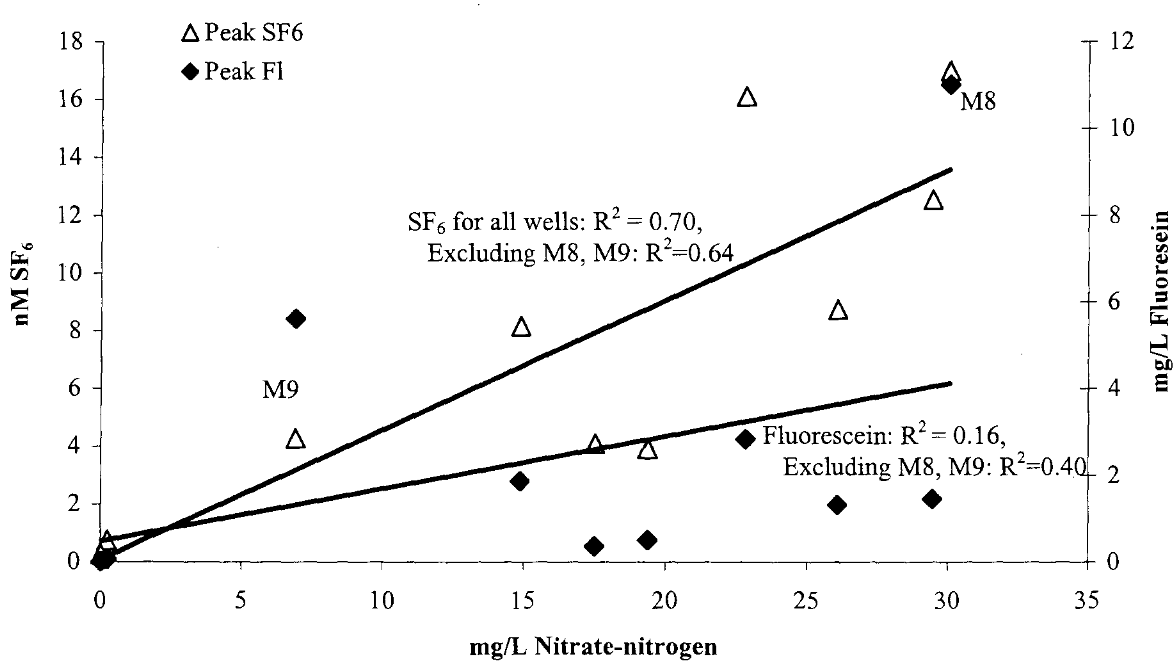

Figure 4- 28. For each well at Magnolia, the highest tracer concentrations are plotted against average nitrate-nitrogen concentration at that well.

Magnolia II Average Total Phosphorus vs Tracers

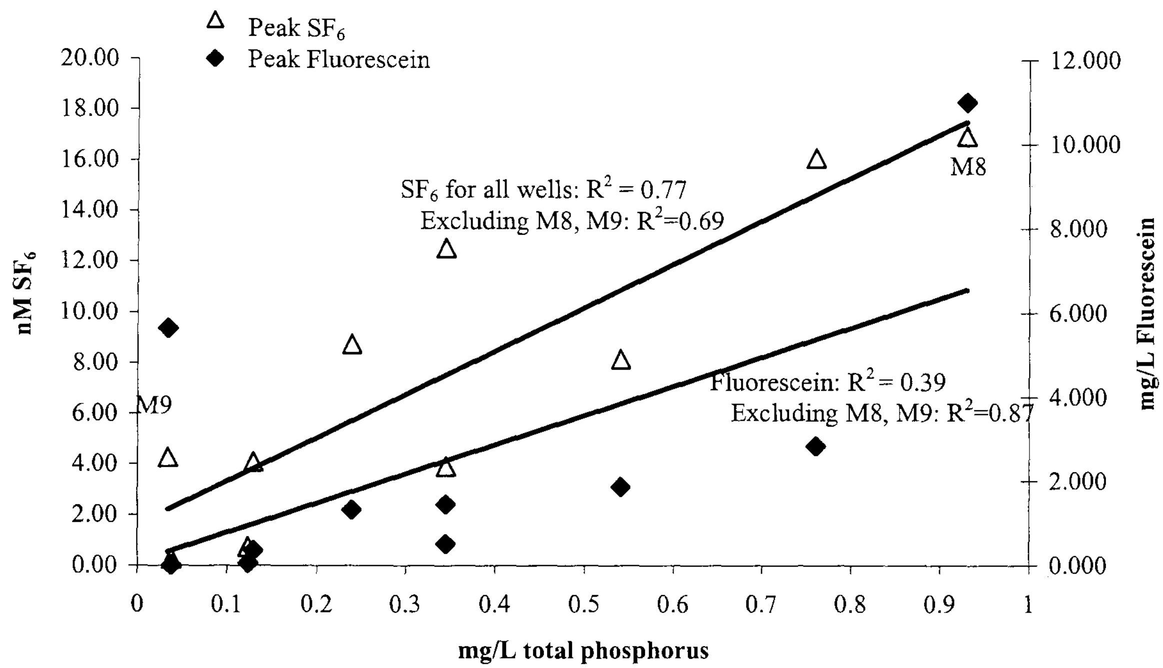

Figure 4- 29. For each well at Magnolia, the highest tracer concentrations are plotted against average total phosphorus concentration at that well.

Hickory Tracer Experiment

The results from the Hickory tracer experiment illustrate the high connectivity between the campground drainfield and the karst aquifer, sinkholes and spring. SF_6 was observed in all of the monitoring wells, Sue Sink, Catfish Hotel and the spring within a few hours of injection (Table 4- 4). Well S2 was installed at the end of a drainfield line and had the highest SF_6 concentration in the initial sample of any well (Figure 4- 14). Well S1, which had the next highest initial SF_6 concentration, was installed above a solution pipe near to a drainfield line. The two wells with the next highest initial SF_6 concentrations were C5 and C6, which were both located just north and east of the drainfield lines. The wells farthest from the injection point, C1, C2, C4 and S3 had the lowest initial SF_6 concentrations (Figure 4- 14).

Fluorescein was found in several wells, the spring and Catfish Hotel. On day 20, 0.017 mg/L of fluorescein was observed at Catfish Hotel. For the previous 16 samples at Catfish Hotel fluorescein measurements had been less than 0.003 mg/L. The amount of fluorescein found in the spring 20 days after injection was relatively small at 0.008 mg/L, but significantly higher than the previous 16 spring samples (less than 0.002 mg/L). The wells with the highest SF_6 concentrations, S1, C5 and C6, also contained the highest fluorescein concentrations (Figure 4- 30, Table 4- 4).

Table 4- 4. The number of days following injection (first value in each column) and the concentration (in parenthesis) of the initial and peak observed concentrations of SF_6 (nM) and fluorescein (mg/L) in the Hickory monitoring wells.

Well ID	Initial Fl	Peak Fl	Initial SF_6 Peak	2nd Peak SF_6
S1	0.42 (0.027)	2.80 (1.336)	0.03 (10.38)	27.93 (12.70)
S2	0.62 (0.009)	-	0.03 (11.43)	1.20 (0.79)
S3	1.22 (0.022)	-	0.06 (1.55)	1.22 (0.51)
S4	0.05 (0.008)	-	0.05 (3.82)	1.21 (0.53)
C1	0.85 (0.005)	-	0.08 (2.32)	0.50 (0.66)
C2	-	-	0.09 (1.55)	0.38 (0.66)
C3	-	-	0.07 (3.50)	0.36 (0.91)
C4	1.23 (0.012)	-	0.08 (1.99)	0.41 (0.71)
C5	1.78 (0.018)	39.88 (0.073)	0.06 (6.26)	0.34 (0.83)
C5	-	-	-	77.04 (1.11)
C6	0.77 (0.015)	3.81 (0.039)	0.05 (8.15)	0.34 (0.83)
C6	-	97.95 (0.113)	-	65.96 (1.20)
Sue Sink	-	-	0.15 (0.98)	2.94 (.21)
Catfish Hotel	20.05 (0.017)	-	0.17 (0.77)	1.81 (0.30)
Spring	20.05 (.008)	-	0.19 (0.51)	1.84 (0.49)
Cave	-	-	-	1.88 (0.31)

Although the velocities calculated from the two tracers were different except for well S3 (Table 4- 5), the correlation between the second SF_6 peak and fluorescein peak concentrations was very high, R^2=0.99. The correlation as expressed by R^2 was greater between fluorescein and the second SF_6 peak than between fluorescein and the initial SF_6 peak, R^2 = 0.28. These correlations are dominated by the extraordinarily high fluorescein measurement in S1 (Figure 4- 30).

The SF_6 data for S1 were unusual in that the concentrations rose to over 10 nM on day 17 and stayed above 10 nM through day 77 (Figure 4- 15). This is an indication that the tracer-laden effluent degassed in the sandy cavity fill material found between the drainfield and the water table and that the soil gas served as a continuous source for SF_6 over the next two months.

Table 4- 5. Rates, in feet per day, calculated from the Hickory tracer experiment. The injection point (Inj.) was in the outflow pipe of the septic tank, just upstream of the distribution box of the drainfield. (n/c = not calculated)

Well ID	Initial Fl	Peak Fl	SF_6 Peak	2nd SF_6 Peak
Inj. to S1	81.90	12.29	1147	1.23
Inj. to S2	n/c	n/c	3257	81.42
Inj. to S3	134.26	n/c	2730	134.3
Inj. to S4	n/c	n/c	2064	85.29
Inj. to C1	n/c	n/c	1753	280.6
Inj. to C2	n/c	n/c	1192	282.4
Inj. to C3	n/c	n/c	1194	232.2
Inj. to C4	84.63	n/c	1301	253.9
Inj. to C5	26.12	1.17	775	136.8
Inj. to C5	n/c	n/c	n/c	0.60
Inj. to C6	52.99	10.71	816	120.0
Inj. to C6	n/c	0.42	n/c	0.62

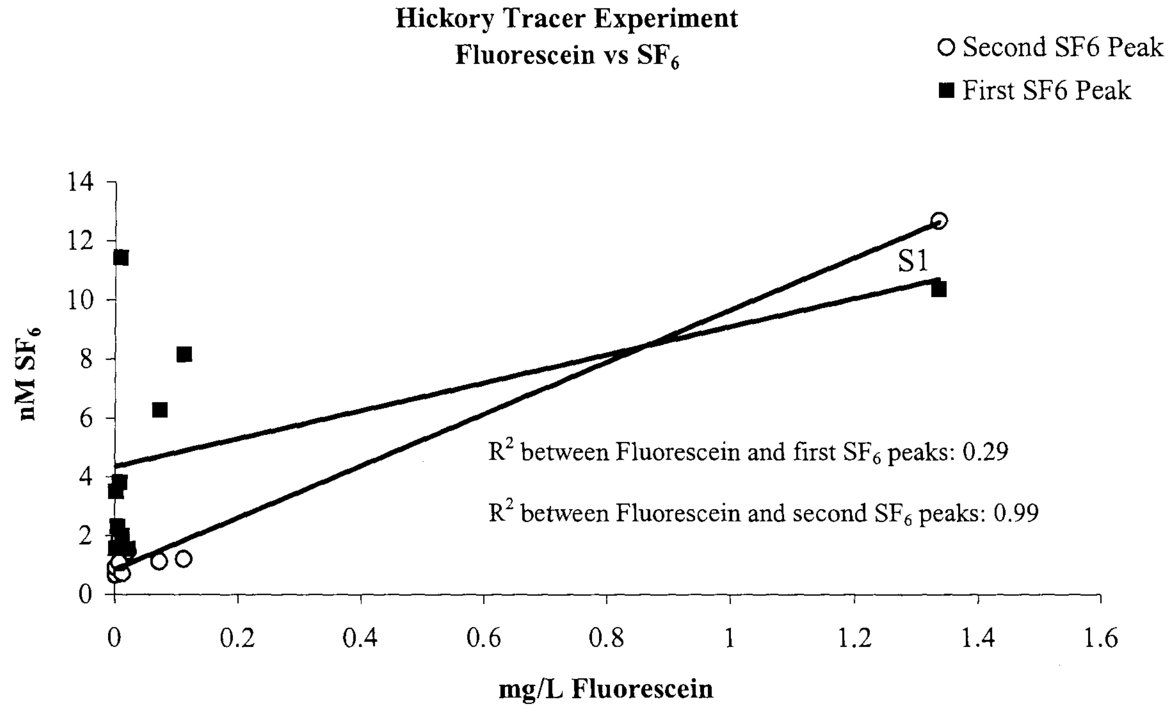

Figure 4- 30. Plot of highest measured SF6 concentrations against the highest measured fluorescein concentration in the wells at Hickory.

Hickory Nutrient and Tracer Data Comparisons

As with the Magnolia data, the tracer data at the Hickory site correlated very well with the nutrient data, strongly indicating that the nutrients found in the well field originate from the septic system. Wells S1, C5 and C6 were the only wells at the Hickory site to have elevated nutrient levels compared to the background wells, and they also had among the highest concentrations of both tracers (Table 4- 6). Well S2 had the highest concentration of SF_6, but the nutrient concentrations were similar to the background wells. A drainfield line ended near well S2, but from the nutrient data it appeared that effluent does not typically flow down its length.

Of the ten wells at the Hickory site, only S1 had both nitrate-nitrogen and total phosphorus concentrations consistently higher than the background wells (Table 4- 6). S1 also had the highest concentrations of both tracers. This suggests that the effluent migrates mainly downwards from the drainfield towards S1. Once it enters the vadose zone, it is slow to mix horizontally with surrounding groundwater and is possibly advected away vertically to mix with groundwater in the cave system.

The nitrate-nitrogen concentration in S1 decreased from a high of 56.1 mg/L on August 22, 2003 just prior to the closure of the campground on September 03, 2003 to to 4.28 ± 0.02 mg/L on January 26, 2004. The campground was reopened on May 3, 2004, and just one week later the nitrate-nitrogen concentrations had increased again in well S1 to 35.95 ± 3.32 mg/L.

Table 4- 6. Highest observed total phosphorus and nitrate-nitrogen concentrations, average nitrate-nitrogen concentration and the peak tracer concentrations for each well at the Hickory site and two background wells

Well ID	High Total P (mg/L)	High NO_3-N (mg/L)	Initial SF_6 Peak (nM)	second SF_6 Peak (nM)	High Fl (mg/L)
CA1	0.028	0.147	-	-	-
MB2	0.474	1.61	-	-	-
S1	4.89	56.1	10.380	12.696	1.34
S2	0.038	1.06	11.426	1.878	0.01
S3	0.703	0.075	1.545	1.450	0.022
S4	0.260	0.489	3.820	1.074	0.008
C1	0.032	0.717 ± 0.180	2.316	0.663	0.005
C2	<0.014	1.61	1.554	0.659	0.002
C3	0.047	1.100	3.504	0.910	0.002
C4	0.027	1.230	1.990	0.710	0.012
C5	0.167	41.3	6.264	1.111	0.073
C6	0.033	22.9	8.154	1.200	0.113

Wells C5 and C6 had nitrate-nitrogen concentrations (but not total phosphorus) that were elevated compared to the background wells. The nitrate-nitrogen concentration in C5 was 41.3 mg/L on August 22, 2003, just prior to the campground closure and decreased to less than 10 mg/L while the campground was closed. On May 10, 2003, a week after the campground had reopened, the nitrate-nitrogen was observed to be 32.7 mg/L in well C5. In well C6, a different pattern was observed than for S1 and C5. In the first five sampling events, the nitrate-nitrogen concentration was 1.43 ± 0.33 mg/L and after the campground closure it was measured to be 22.9 mg/L on October 10, 2003 and 5.21 mg/L on December 03, 2003. Coinciding with the high nitrate-nitrogen concentration (22.9 mg/L) on October 10, 2003 in well C6 was the highest concentration of fluorescein (0.113 mg/L) measured at that well (Figure 4- 24). Unfortunately, the well was damaged during bathhouse renovations, and no further sampling was possible.

Comparison with Previous Studies

Tracer studies using SF_6 and fluorescein have been performed in other non-karst environments in Florida, namely a barrier island (Corbett et al. 2000) and adjacent to seasonally inundated areas (SIAs) (Harden et al. 2003). Transport velocities in these non-karst environments are much slower than measured in this study. In the SIA study the transport rates from the SF_6 tracer were approximately 1 feet/day and a slower rate of 0.2 feet/day was calculated from the fluorescein data (Harden et al. 2003). Similar rates were calculated in the barrier island study, with both SF_6 and fluorescein data yielding 0.5-1.5 feet/day (Corbett et al., 2000).

In contrast, the wells at the Magnolia site indicated an average velocity of 16 ± 8 feet/day from the SF_6 data and 41 ± 35 feet/day from the fluorescein data. These values do not include wells M4 and M10, since the nutrient data showed they were not in the effluent plume. At Hickory the SF_6 derived velocities (from the second peak) were even faster, 161 ± 96 feet/day, and the fluorescein derived rates were 8 ± 6 feet/day. These values, based on peak concentration values, represent some average velocity, velocities based on initial occurrence were faster by about a factor of ten (Table 4- 1 and 4- 4).

The velocities calculated in this study fall within the range of rates from SF_6 tracer experiments in the Florida Keys, another karst environment. Dillon et al. (1999) report velocities ranging from 10 to 260 ft/day and another study reports rates from 3 to 140 ft/day (Dillon et al. 2000), both from SF_6 experiments. The velocities

Conclusions

The wells that had high levels of nitrate-nitrogen also had high levels of one or both tracers, establishing the connection between the septic systems and the groundwater monitoring wells. The results of this study indicate that in the karst environment conventional septic systems do a poor job of attenuating nitrate-nitrogen pollution but are more efficient in removing fecal coliforms. Except for the one sample in well M8, the fecal coliform counts were within the Florida bathing water standard of 200 CFU/100mL, but several were above drinking water standards. The results of this study clearly showed great connectivity between the surficial soils and the underlying karst aquifer at both the Magnolia and Hickory site. Tracer showed up in the wells in the early hours of the experiment. Flow rates were in 10's of feet per day.

At Magnolia, calculated velocities varied from 5 to 100 feet per day and at Hickory they varied from 1 to 280 ft/day. Elevated nutrients were found in wells surrounding the septic systems with nitrate-nitrogen concentrations in impacted wells as great as 20 to 60 mg/L at both the Magnolia and Hickory sites. Well M8 was the most impacted at Magnolia, with concentrations ranging up to 55 mg/L nitrate-nitrogen, 0.92 mg/L total phosphorus and 932 CFU/100 mL. Well S1 was the most impacted at Hickory, with concentrations ranging up to 56 mg/L nitrate, 4.89 mg/L total phosphorus and 99 fecal CFU/100 mL. Background wells had high concentrations of only 1.61 mg/L nitrate, 0.47 mg/L total phosphorus and less than two CFU/100 mL. The most elevated nutrient concentrations were found directly in the flow path of the effluent as indicated by the tracer experiments.

The conclusion of this study is that the proximity and connectivity of the surficial soils and the underlying karst aquifer limits the ability of conventional OSTDS to attenuate nutrient and pathogen concentrations and allows rapid transport in the direction of the nearest surface water body or spring. The results from this study could also be applicable to other waste disposal methods that do not remove nutrients and apply large quantities of water to the soil.

The Department of Health should investigate and recommend alternative treatment options, such as performance-based treatment systems. These systems can be designed to remove nitrogen, phosphorus and fecal coliforms before the effluent is released to the soil environment. Specifications for such systems have been codified in Part IV of Rule 64E-6, Florida Administrative Code. Phase II of this study will replace the conventional OSTDS with such nutrient-removing systems to evaluate their effectiveness.

Acknowledgements

We would like to thank the staff at Manatee Springs State Park for their cooperation and assistance with this study. Thanks also to the Suwannee River Water Management District staff for assistance in site selection and sampling the background wells. We would like to thank J.B. Ritter and Kelly Peeler for their help in the field.

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Appendix 1

Tracer Data

Appendix 1a. Tracer data for the Magnolia II campground tracer experiment. SF_6 concentrations are in nM and fluorescein is expressed as mg/L. "Days" refers to days after the tracer injection.

Well ID	Date/Time	Days	SF_6 Ave	SD	Fl Ave	SD
M1	5/23/03 19:15	-0.65	**0.000**	0.000	**0.006**	
M1	5/24/03 11:42	0.03	**0.345**	0.031	-	
M1	5/24/03 12:50	0.08	**0.140**	0.025	**0.002**	
M1	5/24/03 14:00	0.13	**0.127**	0.005	**0.002**	
M1	5/24/03 15:00	0.17	**0.055**	0.001	**0.005**	
M1	5/24/03 16:00	0.21	**0.000**	0.000	**0.001**	
M1	5/24/03 17:00	0.26	**0.000**	0.000	**0.001**	
M1	5/24/03 18:02	0.30	**0.036**	0.008	**0.002**	
M1	5/24/03 19:06	0.34	**0.051**	0.001	**0.001**	
M1	5/24/03 20:02	0.38	**0.024**	0.001	**0.008**	
M1	5/24/03 21:06	0.43	**0.000**	0.000	-	
M1	5/24/03 22:04	0.47	**0.030**	0.008	**0.005**	
M1	5/24/03 23:24	0.52	**0.049**	0.005	**0.006**	
M1	5/25/03 0:58	0.59	**0.044**	0.008	**0.002**	
M1	5/25/03 2:28	0.65	**0.032**	0.011	**0.001**	
M1	5/25/03 4:06	0.72	**0.028**	0.012	**0.001**	
M1	5/25/03 5:22	0.77	**0.033**	0.006	**0.000**	
M1	5/25/03 7:28	0.86	**0.025**	0.002	**0.001**	
M1	5/25/03 9:02	0.92	**0.034**	0.004	**0.001**	
M1	5/25/03 11:40	1.03	**0.094**	0.001	**0.001**	
M1	5/25/03 14:26	1.15	**0.000**	0.000	**0.002**	
M1	5/25/03 16:48	1.25	**0.085**	0.005	**0.002**	
M1	5/25/03 19:32	1.36	**0.069**	0.008	**0.002**	
M1	5/25/03 22:54	1.50	**0.052**	0.015	**0.003**	
M1	5/26/03 2:46	1.66	**0.042**	0.016	**0.001**	
M1	5/26/03 7:24	1.86	**0.000**	0.000	**0.011**	
M1	5/26/03 11:08	2.01	**0.045**	0.000	**0.003**	
M1	5/26/03 15:14	2.18	**0.000**	0.000	**0.001**	
M1	5/26/03 20:00	2.38	**0.000**	0.000	**0.013**	
M1	5/27/03 6:14	2.81	**0.000**	0.000	**0.033**	
M1	5/27/03 9:40	2.95	**0.000**	0.000	**0.025**	
M1	5/27/03 13:54	3.13	**0.000**	0.000	**0.039**	
M1	5/27/03 17:34	3.28	**0.000**	0.000	**0.042**	
M1	5/28/03 8:12	3.89	**0.086**	0.003	-	
M1	5/28/03 12:16	4.06	**0.049**	0.003	**0.079**	
M1	5/28/03 16:10	4.22	**0.030**	0.002	**0.148**	
M1	5/29/03 9:12	4.93	**0.050**	0.004	**0.181**	
M1	5/29/03 17:04	5.26	**0.000**	0.000	**0.203**	0.011
M1	5/30/03 10:34	5.99	**0.026**	0.008	**0.203**	
M1	5/30/03 17:22	6.27	**0.029**	0.016	**0.280**	

Well ID	Date/Time	Days	SF6 Ave	SD	Fl Ave	SD
M1	5/31/03 9:54	6.96	**0.043**	0.008	**0.207**	
M1	5/31/03 16:50	7.25	**0.047**	0.001	**0.151**	
M1	6/1/03 10:16	7.97	**0.046**	0.001	**0.313**	
M1	6/1/03 16:32	8.24	**0.042**	0.021	**0.149**	
M1	6/3/03 10:56	10.00	**0.243**	0.008	**0.623**	
M1	6/5/03 11:24	12.02	**0.283**	0.020	**0.367**	
M1	6/7/03 16:20	14.23	**1.339**	0.011	**1.210**	
M1	6/9/03 11:06	16.01	**1.885**	0.007	**1.117**	
M1	6/11/03 13:00	18.09	**2.822**	0.001	**1.449**	
M1	6/13/03 10:04	19.97	**2.583**	0.001	**0.467**	
M1	6/16/03 9:42	22.95	**2.487**	0.057	**0.992**	
M1	6/20/03 12:10	27.05	**3.253**	0.011	**1.002**	
M1	6/24/03 10:28	30.98	**5.468**	0.023	**1.225**	
M1	6/30/03 10:22	36.98	**4.692**	0.002	**1.073**	
M1	7/4/03 10:44	40.99	**5.717**	0.027	**0.948**	
M1	7/7/03 10:00	43.96	**8.761**	0.303	**0.530**	
M1	7/11/03 15:28	48.19	**9.682**	0.013	**0.926**	
M1	7/16/03 11:04	53.01	**7.854**	0.027	**0.845**	
M1	7/24/03 16:32	61.24	**12.102**	0.044	**0.799**	
M1	8/1/03 15:34	69.20	**12.537**	0.007	**0.546**	
M1	8/22/03 12:20	90.06	**11.152**	0.077	**0.530**	
M1	9/8/03 12:06	107.05	**9.603**	0.106	**0.450**	
M1	9/19/03 12:32	118.07	**8.408**	0.013	**0.393**	
M1	10/10/03 12:06	139.05	**9.262**	0.003	**0.316**	
M1	11/11/03 12:30	171.07	**10.232**	0.029	**0.271**	
M1	12/3/03 10:42	192.99	**8.126**	0.161	**0.249**	
M1	5/10/04 12:08	352.05	**4.874**	0.211	**0.183**	

Well ID	Date/Time	Days	SF6 Ave	SD	Fl Ave	SD
M2	5/23/03 19:00	-0.66	**0.000**	0.000	**0.006**	
M2	5/24/03 12:07	0.05	**0.190**	0.041	**0.002**	
M2	5/24/03 14:18	0.14	**0.023**	0.019	**0.002**	
M2	5/24/03 17:40	0.28	**0.057**	0.017	**0.004**	
M2	5/24/03 19:38	0.37	**0.056**	0.055	**0.002**	
M2	5/24/03 21:22	0.44	**0.000**	0.000	**0.007**	
M2	5/25/03 0:30	0.57	**0.045**	0.001	**0.003**	
M2	5/25/03 3:00	0.67	**0.050**	0.023	**0.002**	
M2	5/25/03 5:50	0.79	**0.040**	0.007	**0.002**	
M2	5/25/03 8:44	0.91	**0.031**	0.003	**0.003**	
M2	5/25/03 11:22	1.02	**0.100**	0.083	**0.001**	
M2	5/25/03 14:10	1.14	**0.026**	0.006	**0.003**	0.000
M2	5/25/03 16:32	1.24	**0.064**	0.051	**0.006**	
M2	5/25/03 19:14	1.35	**0.072**	0.005	**0.007**	
M2	5/25/03 22:34	1.49	**0.060**	0.005	**0.018**	
M2	5/26/03 2:26	1.65	**0.055**	0.001	**0.022**	
M2	5/26/03 7:04	1.84	**0.000**	0.000	**0.027**	
M2	5/26/03 10:52	2.00	**0.036**	0.007	**0.053**	
M2	5/26/03 15:00	2.17	**0.000**	0.000	**0.052**	
M2	5/26/03 19:48	2.37	**0.000**	0.000	**-**	
M2	5/27/03 6:00	2.80	**0.000**	0.000	**0.284**	0.006
M2	5/27/03 10:14	2.97	**0.000**	0.000	**0.276**	
M2	5/27/03 13:40	3.12	**0.036**	0.009	**0.233**	
M2	5/27/03 17:22	3.27	**0.031**	0.001	**0.368**	
M2	5/28/03 8:00	3.88	**0.131**	0.001	**0.155**	
M2	5/28/03 12:04	4.05	**0.059**	0.003	**0.240**	
M2	5/28/03 16:02	4.22	**0.056**	0.001	**0.436**	
M2	5/29/03 9:00	4.92	**0.047**	0.002	**0.278**	
M2	5/29/03 16:46	5.25	**0.043**	0.003	**0.483**	0.039
M2	5/30/03 10:22	5.98	**0.060**	0.004	**0.473**	
M2	5/30/03 17:10	6.26	**0.098**	0.002	**0.886**	
M2	5/31/03 9:42	6.95	**0.144**	0.002	**0.733**	
M2	5/31/03 16:40	7.24	**0.192**	0.001	**0.749**	
M2	6/1/03 9:36	7.95	**0.299**	0.008	**1.344**	
M2	6/1/03 16:22	8.23	**0.428**	0.001	**1.479**	
M2	6/3/03 10:46	10.00	**0.087**	0.003	**1.357**	
M2	6/5/03 11:12	12.01	**2.280**	0.002	**0.174**	0.012
M2	6/7/03 16:08	14.22	**2.826**	0.001	**0.395**	
M2	6/9/03 10:54	16.00	**1.472**	0.007	**0.416**	
M2	6/11/03 12:48	18.08	**0.661**	0.007	**0.687**	
M2	6/13/03 9:52	19.96	**4.128**	0.035	**1.254**	
M2	6/16/03 9:30	22.94	**8.914**	0.038	**2.843**	
M2	6/20/03 11:54	27.04	**4.841**	0.019	**1.872**	

Well ID	Date/Time	Days	SF6 Ave	SD	Fl Ave	SD
M2	6/24/03 10:16	30.97	**6.247**	0.028	**0.883**	
M2	6/30/03 10:10	36.97	**16.126**	0.119	**1.099**	
M2	7/4/03 10:28	40.98	**12.321**	0.017	**0.635**	
M2	7/7/03 9:48	43.96	**9.371**	0.009	**1.046**	
M2	7/11/03 15:14	48.18	**8.656**	0.035	**1.282**	
M2	7/16/03 10:50	53.00	**9.578**	0.021	**0.817**	
M2	7/24/03 16:28	61.23	**5.804**	0.003	**1.517**	
M2	8/1/03 15:22	69.19	**13.895**	0.038	**1.182**	
M2	8/22/03 12:12	90.06	**12.687**	0.002	**0.497**	
M2	9/8/03 11:54	107.04	**8.110**	0.116	**0.314**	
M2	9/19/03 12:06	118.05	**8.267**	0.013	**0.305**	
M2	10/10/03 11:46	139.04	**6.528**	0.016	**0.219**	
M2	11/11/03 12:08	171.05	**8.964**	0.002	**0.298**	
M2	12/3/03 10:28	192.98	**5.097**	0.039	**0.211**	
M2	5/10/04 11:44	352.04	**1.531**	0.011	**0.068**	

Well ID	Date/Time	Days	SF6 Ave	SD	Fl Ave	SD
M3	5/23/03 17:50	-0.71	**0.000**	0.000	**0.005**	
M3	5/24/03 15:48	0.21	**0.051**	0.024	**0.003**	
M3	5/24/03 22:30	0.48	**0.041**	0.019	**0.003**	
M3	5/25/03 6:56	0.84	**0.049**	0.010	**0.002**	
M3	5/25/03 9:58	0.96	**0.022**	0.011	**0.002**	
M3	5/25/03 12:52	1.08	**0.128**	0.001	**0.003**	
M3	5/25/03 15:20	1.19	**0.036**	0.000	**0.005**	
M3	5/25/03 17:48	1.29	**0.070**	0.009	**-**	
M3	5/25/03 20:36	1.41	**0.000**	0.000	**0.052**	0.001
M3	5/26/03 0:46	1.58	**0.042**	0.001	**0.236**	
M3	5/26/03 3:56	1.71	**0.000**	0.000	**0.341**	
M3	5/26/03 8:36	1.91	**0.000**	0.000	**0.619**	0.103
M3	5/26/03 12:12	2.06	**0.036**	0.004	**0.710**	
M3	5/26/03 16:14	2.22	**0.000**	0.000	**0.581**	
M3	5/26/03 20:54	2.42	**0.005**	0.000	**0.957**	
M3	5/27/03 7:10	2.85	**0.000**	0.000	**1.086**	
M3	5/27/03 11:06	3.01	**0.000**	0.000	**1.328**	
M3	5/27/03 14:50	3.17	**0.000**	0.000	**1.505**	
M3	5/27/03 18:14	3.31	**0.000**	0.000	**1.273**	
M3	5/28/03 9:00	3.92	**0.061**	0.003	**1.850**	
M3	5/28/03 13:02	4.09	**0.052**	0.001	**1.864**	
M3	5/28/03 16:58	4.25	**0.048**	0.002	**1.159**	
M3	5/29/03 10:04	4.97	**0.000**	0.000	**1.599**	
M3	5/29/03 17:58	5.30	**0.000**	0.000	**1.298**	
M3	5/30/03 11:22	6.02	**0.000**	0.000	**1.238**	
M3	5/30/03 18:06	6.30	**0.009**	0.013	**1.080**	
M3?	5/31/03 10:52	7.00	**0.025**	0.002	**0.902**	
M3	5/31/03 17:32	7.28	**0.000**	0.000	**0.883**	
M3	6/1/03 11:12	8.01	**0.000**	0.000	0.913	
M3	6/1/03 17:22	8.27	**0.000**	0.000	**0.859**	
M3	6/3/03 11:42	10.03	**0.173**	0.006	**1.172**	
M3	6/5/03 12:14	12.06	**0.031**	0.000	**0.452**	
M3	6/7/03 17:02	14.26	**0.081**	0.008	**0.497**	
M3	6/9/03 12:04	16.05	**0.148**	0.020	**0.391**	
M3	6/11/03 13:58	18.13	**0.244**	0.008	**0.504**	
M3	6/13/03 10:52	20.00	**0.924**	0.016	**0.535**	
M3	6/16/03 10:40	22.99	**3.104**	0.004	**1.338**	
M3	6/20/03 13:06	27.09	**0.722**	0.003	**0.461**	
M3	6/24/03 11:12	31.01	**2.112**	0.009	**0.581**	
M3	6/30/03 11:06	37.01	**6.212**	0.000	**0.841**	
M3	7/4/03 11:42	41.03	**7.214**	0.017	**0.873**	
M3	7/7/03 10:50	44.00	**7.614**	0.007	**1.130**	0.000
M3	7/11/03 16:20	48.23	**6.337**	0.012	**1.344**	0.026

Well ID	Date/Time	Days	SF6 Ave	SD	Fl Ave	SD
M3	7/16/03 11:52	53.04	**7.506**	0.017	**1.143**	
M3	7/24/03 17:00	61.26	**5.943**	0.012	**1.431**	
M3	8/1/03 14:34	69.15	**7.743**	0.003	**0.801**	
M3	8/22/03 11:46	90.04	**6.765**	0.014	**0.457**	
M3	9/8/03 11:08	107.01	**8.077**	0.033	**0.349**	
M3	9/19/03 11:20	118.02	**8.171**	0.002	**0.348**	
M3	10/10/03 11:10	139.01	**7.076**	0.099	**0.308**	
M3	11/11/03 11:28	171.03	**8.017**	0.008	**0.375**	
M3	12/3/03 9:30	192.94	**4.309**	0.026	**0.275**	
M3	5/10/04 11:12	352.01	**1.415**	0.027	**0.104**	

Well ID	Date/Time	Days	SF6 Ave	SD	Fl Ave	SD
M4	5/23/03 17:40	-0.72	**0.000**	0.000	**0.031**	
M4	5/24/03 16:04	0.22	**0.062**	0.011	**0.001**	
M4	5/24/03 22:42	0.49	**0.007**	0.002	**0.002**	
M4	5/25/03 7:12	0.85	**0.026**	0.001	**0.001**	
M4	5/25/03 10:46	1.00	**0.012**	0.011	**0.002**	
M4	5/25/03 13:42	1.12	**0.000**	0.000	**0.004**	
M4	5/25/03 16:00	1.21	**0.000**	0.000	**0.006**	
M4	5/25/03 18:04	1.30	**0.000**	0.000	**0.010**	
M4	5/25/03 20:52	1.42	**0.053**	0.025	**0.014**	
M4	5/26/03 1:04	1.59	**0.039**	0.000	**0.017**	
M4	5/26/03 4:12	1.72	**0.053**	0.009	**0.020**	
M4	5/26/03 8:54	1.92	**0.043**	0.001	**0.029**	0.004
M4	5/26/03 12:28	2.07	**0.040**	0.002	**0.036**	
M4	5/26/03 16:30	2.23	**0.000**	0.000	**0.037**	
M4	5/26/03 21:08	2.43	**0.000**	0.000	**0.038**	
M4	5/27/03 7:24	2.86	**0.000**	0.000	**0.039**	
M4	5/27/03 11:22	3.02	**0.000**	0.000	**0.043**	0.003
M4	5/27/03 15:02	3.17	**0.000**	0.000	**0.044**	
M4	5/27/03 18:26	3.32	**0.000**	0.000	**0.041**	
M4	5/28/03 9:12	3.93	**0.060**	0.014	**0.043**	
M4	5/28/03 13:12	4.10	**0.040**	0.003	**0.041**	
M4	5/28/03 17:10	4.26	**0.032**	0.002	**0.041**	
M4	5/29/03 10:16	4.97	**0.000**	0.000	**0.043**	0.001
M4	5/29/03 18:12	5.31	**0.000**	0.000	**0.053**	
M4	5/30/03 11:34	6.03	**0.016**	0.006	**0.045**	
M4	5/30/03 18:18	6.31	**0.000**	0.000	**0.041**	
M4	5/31/03 10:52	7.00	**0.251**	0.002	**0.048**	0.000
M4	5/31/03 17:42	7.28	**0.022**	0.008	**0.056**	
M4	6/1/03 11:24	8.02	**0.000**	0.000	**0.052**	
M4	6/1/03 17:34	8.28	**0.000**	0.000	**0.060**	
M4	6/3/03 11:54	10.04	**0.032**	0.004	**0.060**	0.000
M4	6/5/03 12:26	12.07	**0.000**	0.000	**0.025**	
M4	6/7/03 17:12	14.26	**0.000**	0.000	**0.019**	
M4	6/9/03 12:16	16.06	**0.031**	0.002	**0.024**	
M4	6/11/03 14:08	18.14	**0.030**	0.011	**0.025**	
M4	6/13/03 11:04	20.01	**0.045**	0.006	**0.029**	
M4	6/16/03 10:52	23.00	**0.036**	0.001	**0.035**	
M4	6/20/03 13:20	27.10	**0.035**	0.006	**0.032**	0.003
M4	6/24/03 11:24	31.02	**0.047**	0.007	**0.023**	0.000
M4	6/30/03 11:18	37.02	**0.078**	0.010	**0.026**	
M4	7/4/03 11:56	41.04	**0.181**	0.006	**0.052**	0.011
M4	7/7/03 11:00	44.01	**0.229**	0.013	**0.028**	0.010
M4	7/11/03 16:32	48.24	**0.186**	0.038	**0.042**	0.000

Well ID	Date/Time	Days	SF6 Ave	SD	Fl Ave	SD
M4	7/16/03 12:10	53.05	**0.159**	0.004	**0.046**	0.001
M4	7/24/03 17:08	61.26	**0.185**	0.000	**0.026**	
M4	8/1/03 14:22	69.15	**0.112**	0.000	**0.019**	
M4	8/22/03 11:42	90.03	**0.199**	0.007	**0.022**	
M4	9/8/03 10:56	107.00	**0.273**	0.013	**0.023**	
M4	9/19/03 11:08	118.01	**0.640**	0.010	**0.050**	0.001
M4	10/10/03 11:00	139.01	**0.251**	0.004	**0.026**	
M4	11/11/03 11:18	171.02	**0.746**	0.006	**0.040**	
M4	12/3/03 9:18	192.93	**0.488**	0.009	**0.034**	
M4	5/10/04 10:58	352.00	**0.238**	0.026	**0.021**	

Well ID	Date/Time	Days	SF6 Ave	SD	Fl Ave	SD
M5	5/23/03 18:30	-0.68	**0.000**		**0.000**	
M5	5/24/03 12:38	0.07	**0.208**	0.063	**0.003**	
M5	5/24/03 14:51	0.17	**0.115**	0.021	**0.001**	
M5	5/24/03 18:12	0.31	**0.036**	0.030	**0.001**	
M5	5/24/03 19:50	0.37	**0.020**	0.019	**0.002**	
M5	5/24/03 21:50	0.46	**0.029**	0.006	**0.005**	
M5	5/25/03 0:42	0.58			**0.002**	
M5	5/25/03 3:16	0.68	**0.036**	0.008	**0.002**	
M5	5/25/03 6:04	0.80	**0.058**	0.012	**0.158**	
M5	5/25/03 9:14	0.93	**0.000**	0.000	**0.357**	
M5	5/25/03 11:56	1.04	**0.000**	0.000	**0.456**	0.093
M5	5/25/03 14:40	1.16	**0.029**	0.000	**0.942**	0.031
M5	5/25/03 17:00	1.26	**0.000**	0.000	**0.930**	0.102
M5	5/25/03 19:48	1.37	**0.022**	0.000	**0.626**	0.277
M5	5/25/03 23:10	1.51	**0.047**	0.015	**0.880**	0.086
M5	5/26/03 3:04	1.68	**0.050**	0.001	**1.172**	
M5	5/26/03 7:42	1.87	**0.042**	0.000	**1.163**	
M5	5/26/03 11:22	2.02	**0.035**	0.019	**0.878**	
M5	5/26/03 15:28	2.19	**0.000**	0.000	**1.313**	
M5	5/26/03 20:12	2.39	**0.020**	0.019	**0.827**	
M5	5/27/03 6:28	2.82	**0.000**	0.000	**0.961**	
M5	5/27/03 9:58	2.96	**0.000**	0.000	**0.743**	
M5	5/27/03 14:10	3.14	**0.025**	0.007	**0.745**	
M5	5/27/03 17:42	3.28	**0.035**	0.008	**1.054**	
M5	5/28/03 8:22	3.90	**0.097**	0.002	**1.083**	
M5	5/28/03 12:26	4.07	**0.068**	0.001	**0.605**	
M5	5/28/03 16:24	4.23	**0.059**	0.003	**0.895**	
M5	5/29/03 9:26	4.94	**0.048**	0.000	**0.866**	
M5	5/29/03 17:20	5.27	**1.909**	0.002	**0.820**	
M5	5/30/03 10:46	6.00	**0.038**	0.008	**0.685**	
M5	5/30/03 17:32	6.28	**0.042**	0.000	**0.890**	
M5	5/31/03 10:06	6.97	**0.050**	0.001	**0.656**	
M5	5/31/03 17:00	7.26	**0.052**	0.001	**0.421**	
M5	6/1/03 10:28	7.98	**0.044**	0.001	**0.271**	
M5	6/1/03 16:44	8.24	**0.041**	0.007	**0.600**	
M5	6/3/03 11:08	10.01	**0.169**	0.001	**0.864**	
M5	6/5/03 11:36	12.03	**0.212**	0.000	**0.712**	
M5	6/7/03 16:28	14.23	**0.665**	0.039	**-**	
M5	6/9/03 11:20	16.02	**1.177**	0.000	**0.436**	
M5	6/11/03 13:12	18.10	**1.100**	0.006	**0.462**	
M5	6/13/03 10:16	19.97	**0.885**	0.012	**0.468**	
M5	6/16/03 9:56	22.96	**1.122**	0.017	**0.477**	
M5	6/20/03 12:24	27.06	**1.466**	0.006	**0.371**	

Well ID	Date/Time	Days	SF6 Ave	SD	Fl Ave	SD
M5	6/24/03 10:40	30.99	**1.514**	0.000	**0.435**	
M5	6/30/03 10:34	36.99	**1.505**	0.006	**0.229**	
M5	7/4/03 10:58	41.00	**1.872**	0.022	**0.254**	0.046
M5	7/7/03 10:12	43.97	**2.503**	0.020	**0.315**	
M5	7/11/03 15:38	48.20	**2.285**	0.004	**0.360**	
M5	7/16/03 11:16	53.02	**1.902**	0.011	**0.267**	
M5	7/24/03 16:38	61.24	**3.034**	0.017	**0.330**	
M5	8/1/03 15:08	69.18	**4.249**	0.002	**0.288**	
M5	8/22/03 12:08	90.05	**4.950**	0.032	**0.294**	
M5	9/8/03 11:44	107.04	**6.372**	0.001	**0.315**	
M5	9/19/03 11:56	118.04	**6.752**	0.041	**0.254**	
M5	10/10/03 11:38	139.03	**6.967**	0.103	**0.272**	
M5	11/11/03 11:58	171.05	**8.738**	0.037	**0.258**	
M5	12/3/03 10:14	192.97	**7.100**	0.010	**0.274**	
M5	5/10/04 11:54	352.04	**3.723**	0.112	**0.113**	

Well ID	Date/Time	Days	SF6 Ave	SD	Fl Ave	SD
M6	5/23/03 18:05	-0.70	**0.000**	0.000	**0.002**	
M6	5/24/03 15:32	0.19	**0.057**	0.010	**0.003**	
M6	5/24/03 15:32	0.19	**0.059**	0.015	-	
M6	5/25/03 5:08	0.76	**0.012**	0.016	**0.001**	
M6	5/25/03 9:42	0.95	**0.007**	0.013	**0.022**	0.001
M6	5/25/03 12:36	1.07	**0.110**	0.011	**0.045**	0.017
M6	5/25/03 15:06	1.18	**0.024**	0.003	**0.094**	
M6	5/25/03 17:32	1.28	**0.074**	0.006	**0.092**	0.030
M6	5/25/03 20:20	1.39	**0.000**	0.000	**0.087**	
M6	5/26/03 0:28	1.57	**0.036**	0.002	**0.192**	0.001
M6	5/26/03 3:38	1.70	**0.046**	0.001	**0.217**	
M6	5/26/03 8:22	1.90	**0.041**	0.000	**0.242**	
M6	5/26/03 11:54	2.04	**0.037**	0.001	**0.274**	
M6	5/26/03 15:58	2.21	**0.000**	0.000	**0.258**	
M6	5/26/03 20:40	2.41	**0.000**	0.000	**0.213**	
M6	5/27/03 6:56	2.84	**0.000**	0.000	**0.290**	
M6	5/27/03 10:48	3.00	**0.000**	0.000	**0.346**	
M6	5/27/03 14:38	3.16	**0.000**	0.000	**0.359**	
M6	5/27/03 18:02	3.30	**0.000**	0.000	**0.211**	0.084
M6	5/28/03 8:44	3.91	**0.063**	0.045	**0.184**	
M6	5/28/03 12:30	4.07	**0.055**	0.006	**0.332**	
M6	5/28/03 16:44	4.24	**0.048**	0.005	**0.208**	0.008
M6	5/29/03 9:50	4.96	**0.000**	0.000	**0.318**	
M6	5/29/03 17:46	5.29	**0.000**	0.000	**0.240**	
M6	5/30/03 11:10	6.01	**0.028**	0.005	**0.152**	
M6	5/30/03 17:56	6.29	**0.033**	0.013	**0.107**	
M6	5/31/03 10:30	6.98	**0.000**	0.000	**0.085**	
M6	5/31/03 17:22	7.27	**0.021**	0.002	**0.172**	
M6	6/1/03 10:56	8.00	**0.025**	0.000	**0.210**	
M6	6/1/03 17:08	8.26	**0.000**	0.000	**0.160**	0.003
M6	6/3/03 11:30	10.03	**0.046**	0.003	**0.336**	
M6	6/5/03 12:02	12.05	**0.048**	0.007	**0.177**	
M6	6/7/03 16:50	14.25	**0.155**	0.003	**0.188**	
M6	6/9/03 11:50	16.04	**0.300**	0.009	**0.208**	0.019
M6	6/11/03 13:38	18.12	**0.360**	0.011	**0.180**	
M6	6/13/03 10:40	19.99	**0.279**	0.004	**0.159**	
M6	6/16/03 10:28	22.98	**0.429**	0.005	**0.244**	
M6	6/20/03 12:52	27.08	**0.326**	0.004	**0.158**	
M6	6/24/03 11:00	31.01	**0.498**	0.006	**0.200**	0.000
M6	6/30/03 10:56	37.00	**0.772**	0.009	**0.197**	
M6	7/4/03 11:28	41.03	**0.792**	0.007	**0.200**	
M6	7/7/03 10:38	43.99	**1.101**	0.010	**0.199**	
M6	7/11/03 16:08	48.22	**1.090**	0.003	**0.207**	

Well ID	Date/Time	Days	SF6 Ave	SD	Fl Ave	SD
M6	7/16/03 11:40	53.03	**0.951**	0.001	**0.186**	
M6	7/24/03 16:52	61.25	**1.269**	0.004	**0.194**	
M6	8/1/03 14:44	69.16	**1.663**	0.006	**0.103**	
M6	8/22/03 11:56	90.04	**1.854**	0.000	**0.161**	
M6	9/8/03 11:18	107.02	**2.733**	0.000	**0.118**	
M6	9/19/03 11:32	118.03	**3.293**	0.008	**0.196**	0.010
M6	10/10/03 11:20	139.02	**3.490**	0.058	**0.165**	
M6	11/11/03 11:38	171.03	**4.090**	0.008	**0.171**	
M6	12/3/03 9:40	192.95	**2.982**	0.008	**0.167**	
M6	5/10/04 11:22	352.02	**2.577**	0.062	**0.108**	

Well ID	Date/Time	Days	SF6 Ave	SD	Fl Ave	SD
M7	5/23/03 18:15	-0.69	**0.000**	0.000	**0.005**	
M7	5/24/03 15:14	0.18	**0.066**	0.035	**0.003**	
M7	5/24/03 22:18	0.48	**0.000**	0.000	**0.002**	
M7	5/25/03 3:34	0.70	**0.031**	0.010	**0.006**	
M7	5/25/03 6:42	0.83	**0.041**	0.002	**0.017**	
M7	5/25/03 9:28	0.94	**0.000**	0.000	**0.071**	
M7	5/25/03 12:18	1.06	**0.034**	0.008	**0.087**	
M7	5/25/03 14:56	1.17	**0.068**	0.001	**0.177**	
M7	5/25/03 17:16	1.27	**0.058**	0.002	**0.259**	
M7	5/25/03 20:06	1.38	**0.056**	0.001	**0.205**	
M7	5/25/03 23:26	1.52	**0.077**	0.008	**0.165**	
M7	5/26/03 3:24	1.69	**0.063**	0.001	**0.284**	
M7	5/26/03 8:02	1.88	**0.011**	0.001	**0.306**	
M7	5/26/03 11:38	2.03	**0.042**	0.005	**0.303**	
M7	5/26/03 15:44	2.20	**0.000**	0.000	**0.383**	
M7	5/26/03 20:26	2.40	**0.000**	0.000	**0.367**	
M7	5/27/03 6:44	2.83	**0.000**	0.000	**0.220**	
M7	5/27/03 10:34	2.99	**0.000**	0.000	**0.261**	
M7	5/27/03 14:26	3.15	**0.000**	0.000	**0.347**	
M7	5/27/03 17:54	3.29	**0.000**	0.000	**0.357**	0.037
M7	5/28/03 8:34	3.90	**0.076**	0.002	**0.292**	
M7	5/28/03 12:40	4.08	**0.055**	0.003	**0.293**	0.126
M7	5/28/03 16:34	4.24	**0.054**	0.001	**0.079**	0.000
M7	5/29/03 9:38	4.95	**0.027**	0.000	**0.279**	
M7	5/29/03 17:32	5.28	**0.021**	0.009	**0.381**	
M7	5/30/03 10:58	6.00	**0.041**	0.006	**0.142**	
M7	5/30/03 17:44	6.29	**0.038**	0.004	**0.223**	
M7	5/31/03 10:18	6.98	**-**	-	**0.346**	
M7	5/31/03 17:12	7.26	**-**	-	**0.347**	
M7	6/1/03 10:44	7.99	**0.056**	0.005	**0.118**	0.000
M7	6/1/03 16:58	8.25	**0.061**	0.004	**0.359**	
M7	6/3/03 11:20	10.02	**0.236**	0.007	**0.509**	0.000
M7	6/5/03 11:52	12.04	**0.117**	0.001	**0.253**	
M7	6/7/03 16:40	14.24	**0.676**	0.008	**0.288**	
M7	6/9/03 11:36	16.03	**1.085**	0.000	**0.471**	
M7	6/11/03 13:28	18.11	**0.906**	0.001	**0.352**	0.024
M7	6/13/03 10:28	19.98	**0.669**	0.024	**0.368**	
M7	6/16/03 10:10	22.97	**0.994**	0.007	**0.306**	
M7	6/20/03 12:40	27.08	**0.667**	0.004	**0.195**	
M7	6/24/03 10:50	31.00	**1.135**	0.001	**0.241**	
M7	6/30/03 10:46	37.00	**1.365**	0.001	**0.153**	
M7	7/4/03 11:14	41.02	**1.429**	0.007	**0.170**	0.004
M7	7/7/03 10:26	43.98	**1.931**	0.007	**0.197**	

Well ID	Date/Time	Days	SF6 Ave	SD	Fl Ave	SD
M7	7/11/03 15:54	48.21	**1.802**	0.027	**0.223**	
M7	7/16/03 11:28	53.03	**1.445**	0.004	**0.126**	
M7	7/24/03 16:48	61.25	**1.811**	0.009	**0.117**	
M7	8/1/03 14:56	69.17	**2.884**	0.026	**0.197**	
M7	8/22/03 12:00	90.05	**2.728**	0.259	**0.113**	
M7	9/8/03 11:32	107.03	**3.253**	0.035	**0.136**	
M7	9/19/03 11:44	118.04	**3.139**	0.003	**0.109**	
M7	10/10/03 11:28	139.03	**3.666**	0.012	**0.127**	
M7	11/11/03 11:48	171.04	**3.912**	0.015	**0.121**	
M7	12/3/03 9:52	192.96	**3.135**	0.022	**0.114**	
M7	5/10/04 11:30	352.03	**2.022**	0.049	**0.057**	

Well ID	Date/Time	Days	SF6 Ave	SD	Fl Ave	SD
M8	5/23/03 18:15	-0.69	**0.000**	0.000	**0.002**	
M8	5/24/03 12:25	0.06	**0.057**	0.014	**0.002**	
M8	5/24/03 14:38	0.16	**0.029**	0.001	**0.002**	
M8	5/24/03 17:22	0.27	**0.043**	0.009	**0.005**	
M8	5/24/03 19:24	0.36	**0.060**	0.019	**0.004**	
M8	5/24/03 21:36	0.45	**0.054**	0.026	**0.003**	
M8	5/25/03 0:16	0.56	**0.073**	0.047	**0.005**	
M8	5/25/03 2:46	0.66	**0.052**	0.002	**0.397**	
M8	5/25/03 5:38	0.78	**0.030**	0.008	**2.583**	
M8	5/25/03 8:32	0.90	**0.048**	0.011	**5.510**	
M8	5/25/03 11:02	1.01	**0.034**	0.001	**7.938**	0.444
M8	5/25/03 13:58	1.13	**0.057**	0.040	**11.009**	1.308
M8	5/25/03 16:14	1.22	**0.107**	0.003	**9.182**	0.101
M8	5/25/03 18:58	1.34	**0.007**	0.014	**10.053**	0.287
M8	5/25/03 22:16	1.47	**0.068**	0.003	**8.354**	0.075
M8	5/26/03 2:00	1.63	**0.045**	0.014	**8.478**	0.054
M8	5/26/03 6:48	1.83	**0.056**	0.004	**8.065**	0.285
M8	5/26/03 10:38	1.99	**0.048**	0.002	**7.303**	
M8	5/26/03 14:46	2.16	**0.000**	0.000	**5.562**	
M8	5/26/03 19:34	2.36	**0.000**	0.000	**5.368**	
M8	5/27/03 5:46	2.79	**0.000**	0.000	**7.166**	
M8	5/27/03 9:26	2.94	**0.007**	0.010	**5.777**	
M8	5/27/03 13:26	3.11	**0.035**	0.004	**7.612**	
M8	5/27/03 17:12	3.26	**0.027**	0.008	**6.866**	
M8	5/28/03 7:50	3.87	**0.138**	0.001	**8.540**	
M8	5/28/03 11:54	4.04	**0.075**	0.001	**8.737**	
M8	5/28/03 15:48	4.21	**0.063**	0.009	**7.303**	
M8	5/29/03 8:48	4.91	**0.050**	0.001	**7.852**	
M8	5/29/03 16:34	5.24	**0.048**	0.001	**7.433**	
M8	5/30/03 10:08	5.97	**0.051**	0.001	**7.266**	
M8	5/30/03 17:00	6.26	**0.075**	0.005	**6.269**	
M8	5/31/03 9:30	6.94	**0.097**	0.000	**5.368**	
M8	5/31/03 16:30	7.23	**0.081**	0.003	**5.701**	
M8	6/1/03 9:22	7.94	**0.120**	0.003	**6.041**	
M8	6/1/03 16:08	8.22	**0.136**	0.003	**5.644**	
M8	6/3/03 10:34	9.99	**0.338**	0.000	**7.997**	
M8	6/5/03 11:02	12.01	**1.891**	0.011	**4.849**	0.026
M8	6/7/03 15:58	14.21	**4.561**	0.007	**3.600**	
M8	6/9/03 10:42	15.99	**8.136**	0.005	**5.256**	
M8	6/11/03 12:36	18.07	**7.179**	0.018	**5.598**	
M8	6/13/03 9:40	19.95	**5.592**	0.012	**5.216**	
M8	6/16/03 9:18	22.93	**5.892**	0.032	**5.438**	
M8	6/20/03 11:38	27.03	**5.794**	0.020	**5.262**	

Well ID	Date/Time	Days	SF6 Ave	SD	Fl Ave	SD
M8	6/24/03 10:06	30.97	**8.995**	0.045	**2.823**	
M8	6/30/03 10:00	36.96	**9.333**	0.077	**2.355**	
M8	7/4/03 10:16	40.97	**11.041**	0.023	**2.430**	
M8	7/7/03 9:36	43.95	**13.550**	0.040	**2.420**	
M8	7/11/03 15:04	48.18	**10.920**	0.048	**2.823**	
M8	7/16/03 10:38	52.99	**10.049**	0.041	**2.487**	
M8	7/24/03 16:18	61.23	**11.532**	0.063	**2.478**	
M8	8/1/03 15:44	69.20	**16.994**	0.063	**1.227**	
M8	8/22/03 12:30	90.07	**12.401**	0.025	**0.894**	0.092
M8	9/8/03 12:18	107.06	**9.368**	0.068	**0.516**	0.112
M8	9/19/03 12:20	118.06	**9.095**	0.043	**0.639**	
M8	10/10/03 11:56	139.04	**6.654**	0.041	**0.386**	
M8	11/11/03 12:18	171.06	**4.574**	0.013	**0.444**	
M8	12/3/03 10:56	193.00	**5.027**	0.039	**0.356**	
M8	5/10/04 12:08	352.05	**2.123**	0.014	**0.115**	0.001

Well ID	Date/Time	Days	SF6 Ave	SD	Fl Ave	SD
M9	5/23/03 17:20	-0.73	**0.000**	#DIV/0!	**0.002**	
M9	5/24/03 16:20	0.23	**0.047**	0.011	**0.008**	
M9	5/24/03 22:54	0.50	**0.025**	0.004	**0.003**	
M9	5/25/03 7:56	0.88	**0.025**	0.008	**0.042**	0.001
M9	5/25/03 10:12	0.97	**0.027**	0.000	**0.341**	
M9	5/25/03 13:12	1.10	**0.000**	0.000	**1.175**	0.220
M9	5/25/03 15:34	1.20	**0.000**	0.000	**3.212**	0.176
M9	5/25/03 18:22	1.31	**0.092**	0.005	**3.527**	0.184
M9	5/25/03 21:10	1.43	**0.083**	0.001	**4.455**	
M9	5/26/03 1:20	1.60	**0.083**	0.008	**5.600**	0.127
M9	5/26/03 6:10	1.80	**0.080**	0.003	**5.618**	0.127
M9	5/26/03 8:12	1.89	**0.049**	0.004	**4.704**	
M9	5/26/03 12:44	2.08	**0.010**	0.014	**3.175**	
M9	5/26/03 14:46	2.16	**0.000**	0.000	**1.695**	
M9	5/26/03 21:24	2.44	**0.000**	0.000	**2.814**	
M9	5/27/03 7:40	2.87	**0.000**	0.000	**1.748**	
M9	5/27/03 11:38	3.03	**0.010**	0.014	**2.124**	
M9	5/27/03 15:14	3.18	**0.000**	0.000	**2.073**	
M9	5/27/03 18:36	3.32	**0.011**	0.016	**1.512**	
M9	5/28/03 9:26	3.94	**0.036**	0.026	**1.433**	0.015
M9	5/28/03 13:26	4.11	**0.049**	0.003	**1.469**	0.021
M9	5/28/03 17:22	4.27	**0.057**	0.001	**1.063**	
M9	5/29/03 10:28	4.98	**0.064**	0.037	**1.097**	
M9	5/29/03 18:24	5.31	**2.560**	0.021	**0.536**	
M9	5/30/03 11:46	6.04	**0.005**	0.007	**0.527**	
M9	5/30/03 18:32	6.32	**0.000**	0.000	**0.326**	
M9	5/31/03 11:04	7.01	**0.028**	0.007	**0.692**	
M9	5/31/03 17:52	7.29	**0.000**	0.000	**0.326**	
M9	6/1/03 11:40	8.03	**0.121**	0.029	**1.306**	
M9	6/1/03 17:46	8.29	**0.107**	0.003	**0.809**	
M9	6/3/03 12:06	10.05	**0.293**	0.014	**1.475**	0.027
M9	6/5/03 12:38	12.07	**0.041**	0.016	**0.323**	
M9	6/7/03 17:24	14.27	**0.062**	0.000	**0.199**	
M9	6/9/03 12:32	16.07	**0.266**	0.003	**0.160**	
M9	6/11/03 14:20	18.14	**0.073**	0.008	**0.049**	
M9	6/13/03 11:16	20.02	**0.094**	0.019	**0.113**	
M9	6/16/03 11:10	23.01	**1.714**	0.004	**0.195**	
M9	6/20/03 13:36	27.11	**0.164**	0.010	**0.052**	
M9	6/24/03 10:38	30.99	**0.263**	0.031	**0.079**	
M9	6/30/03 11:30	37.03	**1.901**	0.011	**0.141**	
M9	7/4/03 12:12	41.06	**0.755**	0.009	**0.101**	
M9	7/7/03 11:16	44.02	**0.935**	0.015	**0.086**	
M9	7/11/03 16:44	48.24	**0.876**	0.003	**0.057**	

Well ID	Date/Time	Days	SF6 Ave	SD	Fl Ave	SD
M9	7/16/03 12:20	53.06	**1.185**	0.005	**0.091**	
M9	7/24/03 17:12	61.26	**0.914**	0.007	**0.148**	
M9	8/1/03 14:10	69.14	**1.389**	0.006	**0.068**	
M9	8/22/03 10:32	89.99	**0.581**	0.002	**0.031**	
M9	9/8/03 10:32	106.99	**0.543**	0.003	**0.030**	
M9	9/19/03 10:56	118.00	**1.551**	0.006	**0.092**	
M9	10/10/03 10:50	139.00	**0.310**	0.014	**0.026**	
M9	11/11/03 11:06	171.01	**4.268**	0.010	**0.144**	
M9	12/3/03 9:08	192.93	**1.560**	0.010	**0.068**	
M9	5/10/04 10:46	352.00	**2.200**	0.018	**0.091**	

Well ID	Date/Time	Days	SF6 Ave	SD	Fl Ave	SD
M10	5/23/03 17:05	-0.74	**0.000**	0.000	**0.001**	
M10	5/24/03 16:48	0.25	**0.086**	0.011	**0.008**	
M10	5/24/03 23:06	0.51	**0.000**	0.000	**0.001**	
M10	5/25/03 8:20	0.89	**0.021**	0.000	**0.001**	
M10	5/25/03 10:30	0.98	**0.000**	0.000	**0.005**	
M10	5/25/03 13:26	1.11	**0.000**	0.000	**0.001**	
M10	5/25/03 15:46	1.20	**0.000**	0.000	**0.001**	
M10	5/25/03 18:42	1.33	**0.000**	0.000	**0.002**	
M10	5/25/03 21:30	1.44	**0.022**	0.003	**0.002**	
M10	5/26/03 1:40	1.62	**0.053**	0.000	**0.002**	
M10	5/26/03 6:30	1.82	**0.042**	0.003	**0.001**	
M10	5/26/03 9:28	1.94	**0.032**	0.010	**0.001**	
M10	5/26/03 13:00	2.09	**0.000**	0.000	**0.001**	
M10	5/26/03 17:02	2.26	**0.035**	0.010	**0.005**	
M10	5/26/03 21:38	2.45	**0.000**	0.000	**0.001**	
M10	5/27/03 7:54	2.88	**0.000**	0.000	**0.001**	0.000
M10	5/27/03 11:56	3.04	**0.000**	0.000	**0.001**	
M10	5/27/03 15:26	3.19	**0.000**	0.000	**0.001**	0.000
M10	5/27/03 18:46	3.33	**0.000**	0.000	**0.001**	
M10	5/28/03 9:38	3.95	**0.025**	0.017	**0.002**	
M10	5/28/03 13:38	4.12	**0.024**	0.007	**0.001**	
M10	5/28/03 17:10	4.26	**0.037**	0.008	**0.006**	
M10	5/29/03 10:40	4.99	**0.000**	0.000	**0.002**	
M10	5/29/03 18:38	5.32	**0.000**	0.000	**0.001**	
M10	5/30/03 11:58	6.05	**0.000**	0.000	**0.001**	
M10	5/30/03 18:44	6.33	**0.000**	0.000	**0.002**	
M10	5/31/03 11:16	7.02	**0.000**	0.000	**0.002**	
M10	5/31/03 18:02	7.30	**0.012**	0.016	**0.001**	
M10	6/1/03 11:54	8.04	**0.000**	0.000	**0.002**	
M10	6/1/03 17:58	8.30	**0.005**	0.003	**0.002**	
M10	6/3/03 12:16	10.06	**0.000**	0.000	**0.002**	
M10	6/5/03 12:50	12.08	**0.000**	0.000	**0.002**	
M10	6/7/03 17:34	14.28	**0.000**	0.000	**0.002**	
M10	6/9/03 12:44	16.08	**0.000**	0.000	**0.005**	
M10	6/11/03 14:32	18.15	**0.000**	0.000	**0.001**	
M10	6/13/03 11:28	20.03	**0.000**	0.000	**0.001**	
M10	6/16/03 11:22	23.02	**0.000**	0.000	**0.002**	
M10	6/20/03 13:50	27.12	**0.000**	0.000	**0.002**	0.001
M10	6/24/03 11:48	31.04	**0.000**	0.000	**0.002**	
M10	6/30/03 11:42	37.03	**0.020**	0.003	**0.002**	
M10	7/4/03 12:24	41.06	**0.044**	0.010	**0.002**	
M10	7/7/03 11:30	44.03	**0.133**	0.004	**0.002**	
M10	7/11/03 16:56	48.25	**0.046**	0.008	**0.001**	

Well ID	Date/Time	Days	SF6 Ave	SD	Fl Ave	SD
M10	7/16/03 12:32	53.07	**0.000**	0.000	**0.003**	
M10	7/24/03 17:22	61.27	**0.000**	0.000	**0.003**	
M10	8/1/03 13:58	69.13	**0.000**	0.000	**0.002**	
M10	8/22/03 11:30	90.03	**0.000**	0.000	**0.003**	0.0001
M10	9/8/03 10:30	106.98	**0.000**	0.000	**0.001**	
M10	9/19/03 10:44	117.99	**0.000**	0.000	**0.002**	
M10	10/10/03 10:44	138.99	**0.000**	0.000	**0.001**	
M10	11/11/03 10:52	171.00	**0.271**	0.008	**0.010**	
M10	12/3/03 8:56	192.92	**0.188**	0.009	**0.009**	
M10	5/10/04 10:38	351.99	**0.069**	0.021	**0.003**	

Appendix 1b. Tracer data for the Hickory campground tracer experiment. SF_6 concentrations are in nM and fluorescein is expressed as mg/L. "Days" refers to days after the tracer injection.

Well ID	Date/Time	Days	SF6 Ave	SD	Fl Ave	SD
S1	7/3/03 20:00	-0.77	**0.000**	0.000	**0.001**	
S1	7/4/03 15:14	0.03	**10.380**	0.030	**0.000**	
S1	7/4/03 16:34	0.08	**1.880**	0.000	**0.000**	
S1	7/4/03 18:44	0.17	**0.086**	0.008	**0.000**	
S1	7/4/03 21:00	0.27	**0.797**	0.007	**0.001**	
S1	7/5/03 0:38	0.42	**0.843**	0.004	**0.027**	
S1	7/5/03 4:40	0.59	**0.014**	0.020	**0.064**	
S1	7/5/03 8:40	0.76	**0.032**	0.003	**0.116**	
S1	7/5/03 12:48	0.93	**0.193**	0.001	**0.236**	
S1	7/5/03 18:42	1.17	**0.200**	0.008	**0.247**	
S1	7/5/03 21:16	1.28	**0.108**	0.001	**0.584**	0.029
S1	7/6/03 0:44	1.42	**0.264**	0.003	**0.577**	
S1	7/6/03 6:46	1.68	**0.255**	0.001	**1.025**	
S1	7/6/03 12:40	1.92	**0.264**	0.005	**1.114**	
S1	7/6/03 18:44	2.17	**0.255**	0.002	**1.216**	0.016
S1	7/7/03 3:00	2.52	**0.387**	0.002	**1.073**	
S1	7/7/03 9:44	2.80	**0.387**	0.005	**1.336**	0.061
S1	7/8/03 9:34	3.79	**0.311**	0.008	**1.258**	
S1	7/9/03 10:08	4.82	**0.271**	0.005	**1.101**	
S1	7/10/03 10:08	5.82	**0.303**	0.007	**1.020**	
S1	7/11/03 10:56	6.85	**0.378**	0.004	**0.920**	0.103
S1	7/12/03 15:28	8.04	**0.623**	0.006	**0.759**	
S1	7/13/03 11:56	8.89	**1.794**	0.001	**0.826**	
S1	7/14/03 10:48	9.84	**5.966**	0.030	**0.934**	
S1	7/16/03 15:30	12.04	**3.772**	0.001	**0.767**	
S1	7/18/03 13:42	13.97	**5.746**	0.007	**0.684**	
S1	7/21/03 16:44	17.09	**10.778**	0.064	**0.836**	
S1	7/24/03 15:16	20.03	**12.166**	0.112	**0.596**	
S1	7/28/03 12:50	23.93	**12.502**	0.088	**0.442**	
S1	8/1/03 12:44	27.92	**12.696**	0.070	**0.366**	
S1	8/4/03 12:12	30.90	**10.901**	0.009	**0.371**	
S1	8/13/03 10:18	39.82	**11.696**	0.097	**0.190**	
S1	8/22/03 10:16	48.82	**11.489**	0.029	**0.277**	0.012
S1	9/8/03 13:42	65.97	**12.459**	0.074	**0.189**	
S1	9/19/03 13:52	76.97	**11.880**	0.039	**0.229**	
S1	10/10/03 12:54	97.93	**4.994**	0.002	**0.107**	
S1	12/3/2003 11:50	151.89	**1.139**	0.065	**0.033**	
S1	5/10/04 13:12	310.94	**0.261**	0.062	**0.006**	0.000

Well ID	Date/Time	Days	SF6 Ave	SD	Fl Ave	SD
S2	7/3/03 19:28	-0.79	**0.050**	0.024	**0.001**	
S2	7/4/03 15:14	0.03	**11.426**	0.112	**0.000**	
S2	7/4/03 17:00	0.10	**1.878**	0.004	**0.000**	
S2	7/4/03 19:14	0.20	**0.068**	0.010	**0.000**	
S2	7/4/03 21:36	0.29	**1.084**	0.002	**0.000**	
S2	7/5/03 1:12	0.44	**0.893**	0.011	**0.000**	
S2	7/5/03 5:12	0.61	**-**	-	**0.001**	
S2	7/5/03 9:08	0.78	**0.034**	0.000	**0.009**	
S2	7/5/03 13:04	0.94	**0.240**	0.014	**0.001**	
S2	7/5/03 19:10	1.19	**0.787**	0.003	**0.000**	
S2	7/6/03 1:14	1.45	**0.191**	0.001	**0.001**	
S2	7/6/03 7:16	1.70	**0.030**	0.004	**0.001**	
S2	7/6/03 13:18	1.95	**0.153**	0.000	**0.000**	
S2	7/6/03 19:16	2.20	**0.246**	0.002	**0.000**	
S2	7/7/03 3:28	2.54	**0.228**	0.011	**0.000**	
S2	7/7/03 10:14	2.82	**0.225**	0.006	**0.000**	
S2	7/8/03 10:04	3.81	**0.153**	0.004	**0.000**	
S2	7/9/03 10:28	4.83	**0.031**	0.004	**0.000**	
S2	7/10/03 10:38	5.84	**0.033**	0.012	**0.000**	
S2	7/11/03 11:26	6.87	**0.029**	0.003	**0.001**	
S2	7/12/03 15:52	8.06	**0.010**	0.014	**0.002**	
S2	7/13/03 12:24	8.91	**0.000**	0.000	**0.001**	
S2	7/14/03 10:12	9.82	**0.010**	0.014	**0.001**	
S2	7/16/03 14:32	12.00	**0.000**	0.000	**0.000**	
S2	7/18/03 12:20	13.91	**0.000**	0.000	**0.000**	
S2	7/21/03 15:12	17.03	**0.000**	0.000	**0.001**	
S2	7/24/03 14:06	19.98	**0.068**	0.010	**0.001**	
S2	7/28/03 11:48	23.89	**0.020**	0.015	**0.005**	
S2	8/1/03 11:18	27.87	**0.119**	0.003	**0.001**	
S2	8/4/03 10:46	30.84	**0.118**	0.000	**0.002**	
S2	8/13/03 9:44	39.80	**0.071**	0.001	**0.000**	
S2	8/22/03 9:48	48.80	**0.047**	0.000	**0.000**	
S2	9/8/03 13:16	65.95	**0.038**	0.000	**0.000**	
S2	9/19/03 13:24	76.95	**0.082**	0.007	**0.001**	

Well ID	Date/Time	Days	SF6 Ave	SD	Fl Ave	SD
S3	7/3/03 18:56	-0.82	**0.105**	0.002	**0.001**	
S3	7/4/03 15:56	0.06	**1.545**	0.005	**0.001**	
S3	7/4/03 17:46	0.13	**1.450**	0.005	**0.002**	
S3	7/4/03 19:52	0.22	**1.012**	0.005	**0.001**	
S3	7/4/03 22:06	0.32	**0.967**	0.004	**0.001**	
S3	7/5/03 1:50	0.47	**0.844**	0.003	**0.001**	
S3	7/5/03 5:46	0.63	**0.018**	0.001	**0.006**	
S3	7/5/03 9:38	0.80	**0.270**	0.066	**0.001**	
S3	7/5/03 13:40	0.96	**0.223**	0.018	**0.007**	
S3	7/5/03 19:40	1.21	**0.510**	0.005	**0.022**	
S3	7/6/03 1:44	1.47	**0.166**	0.001	**0.001**	
S3	7/6/03 7:46	1.72	**0.142**	0.006	**0.001**	
S3	7/6/03 13:52	1.97	**0.147**	0.004	**0.000**	
S3	7/7/03 4:00	2.56	**0.195**	0.003	**0.002**	
S3	7/7/03 10:44	2.84	**0.175**	0.003	**0.000**	
S3	7/8/03 10:28	3.83	**0.099**	0.000	**0.001**	
S3	7/9/03 11:02	4.85	**0.033**	0.007	**0.000**	
S3	7/10/03 11:16	5.86	**0.030**	0.004	**0.000**	
S3	7/11/03 11:58	6.89	**0.022**	0.002	**0.000**	
S3	7/12/03 16:20	8.07	**0.022**	0.015	**0.000**	
S3	7/13/03 12:56	8.93	**0.000**	0.000	**0.000**	
S3	7/14/03 10:00	9.81	**0.034**	0.002	**0.000**	
S3	7/18/03 11:54	13.89	**0.000**	0.000	**0.001**	
S3	7/21/03 14:48	17.01	**0.000**	0.000	**0.001**	
S3	7/24/03 13:46	19.97	**0.000**	0.000	**0.000**	
S3	7/28/03 12:02	23.90	**0.000**	0.000	**0.001**	
S3	8/1/03 10:50	27.85	**0.000**	0.000	**0.001**	
S3	8/4/03 10:16	30.82	**0.000**	0.000	**0.001**	
S3	8/13/03 9:20	39.78	**0.000**	0.000	**0.002**	
S3	8/22/03 9:46	48.80	**0.000**	0.000	**0.001**	
S3	9/8/03 12:54	65.93	**0.000**	0.000	**0.001**	
S3	9/19/03 13:08	76.94	**0.024**	0.001	**0.001**	

Well ID	Date/Time	Days	SF6 Ave	SD	Fl Ave	SD
S4	7/3/03 19:44	-0.78	**0.050**	0.001	**-0.003**	
S4	7/4/03 15:36	0.04	**3.820**	0.000	**0.008**	
S4	7/4/03 17:20	0.12	**1.074**	0.002	**0.000**	
S4	7/4/03 19:24	0.20	**0.503**	0.006	**0.000**	
S4	7/4/03 21:52	0.31	**0.810**	0.003	**0.000**	
S4	7/5/03 1:32	0.46	**0.429**	0.005	**0.001**	
S4	7/5/03 5:28	0.62	**0.000**	0.000	**0.001**	
S4	7/5/03 9:22	0.78	**0.000**	0.000	**0.000**	
S4	7/5/03 13:20	0.95	**0.179**	0.005	**0.001**	
S4	7/5/03 19:24	1.20	**0.534**	0.002	**0.000**	
S4	7/6/03 1:28	1.46	**0.136**	0.001	**0.002**	
S4	7/6/03 7:30	1.71	**0.103**	0.000	**0.000**	
S4	7/6/03 13:32	1.96	**0.100**	0.003	**0.001**	
S4	7/6/03 19:30	2.21	**0.000**		**0.003**	
S4	7/7/03 3:44	2.55	**0.180**	0.001	**0.000**	
S4	7/7/03 10:28	2.83	**0.174**	0.001	**0.000**	
S4	7/8/03 10:16	3.82	**0.000**	0.000	**0.000**	
S4	7/9/03 10:42	4.84	**0.021**	0.000	**0.000**	
S4	7/10/03 10:56	5.85	**0.050**	0.006	**0.000**	
S4	7/11/03 11:42	6.88	**0.021**	0.007	**0.000**	
S4	7/12/03 16:04	8.06	**0.000**	0.000	**0.000**	
S4	7/13/03 12:38	8.92	**0.031**	0.009	**0.000**	
S4	7/14/03 10:24	9.83	**0.000**	0.000	**0.000**	
S4	7/16/03 14:44	12.01	**0.000**	0.000	**0.000**	
S4	7/18/03 12:12	13.90	**0.000**	0.000	**0.000**	
S4	7/21/03 15:00	17.02	**0.000**	0.000	**0.000**	
S4	7/24/03 13:56	19.97	**0.000**	0.000	**0.000**	
S4	7/28/03 12:16	23.91	**0.000**	0.000	**0.004**	
S4	8/1/03 11:04	27.86	**0.000**	0.000	**0.000**	
S4	8/4/03 10:34	30.83	**0.000**	0.000	**0.001**	
S4	8/13/03 9:32	39.79	**0.000**	0.000	**0.000**	
S4	8/22/03 10:04	48.81	**0.000**	0.000	**0.001**	
S4	9/8/03 13:06	65.94	**0.000**	0.000	**0.000**	
S4	9/19/03 13:40	76.96	**0.000**	0.000	**0.000**	

Well ID	Date/Time	Days	SF6 Ave	SD	Fl Ave	SD
C1	7/4/03 8:58	-0.23	**0.067**	0.009	**0.002**	
C1	7/4/03 16:16	0.07	**2.316**	0.003	**0.001**	
C1	7/4/03 17:44	0.13	**0.242**	0.003	**0.000**	
C1	7/4/03 20:12	0.24	**0.034**	0.000	**0.000**	
C1	7/4/03 23:58	0.39	**0.595**	0.018	**0.000**	
C1	7/5/03 2:28	0.50	**0.663**	0.017	**0.000**	
C1	7/5/03 6:52	0.68	**0.000**	0.000	**0.001**	
C1	7/5/03 10:56	0.85	**0.332**	0.121	**0.005**	
C1	7/5/03 15:24	1.04	**0.222**	0.008	**0.001**	
C1	7/5/03 20:38	1.25	**0.245**	0.002	**0.000**	
C1	7/6/03 2:46	1.51	**0.022**	0.000	**0.002**	
C1	7/6/03 8:44	1.76	**0.116**	0.001	**0.000**	
C1	7/6/03 14:58	2.02	**0.115**	0.009	**0.000**	
C1	7/6/03 20:44	2.26	**0.190**	0.002	**0.000**	
C1	7/7/03 5:20	2.62	**0.216**	0.004	**0.001**	0.000
C1	7/7/03 11:50	2.89	**0.176**	0.000	**0.000**	
C1	7/8/03 11:22	3.87	**0.150**	0.000	**0.000**	
C1	7/9/03 12:16	4.91	**0.044**	0.012	**0.000**	
C1	7/10/03 12:22	5.91	**0.088**	0.004	**0.002**	
C1	7/11/03 13:20	6.95	**0.021**	0.003	**0.000**	
C1	7/12/03 17:08	8.11	**0.030**	0.000	**0.000**	
C1	7/13/03 13:56	8.97	**0.051**	0.002	**0.000**	
C1	7/14/03 11:44	9.88	**0.000**	0.000	**0.000**	
C1	7/18/03 13:16	13.95	**0.000**	0.000	**0.000**	
C1	7/21/03 16:14	17.07	**0.000**	0.000	**0.000**	
C1	7/24/03 14:50	20.01	**0.000**	0.000	**0.000**	
C1	7/28/03 11:52	23.89	**0.000**	0.000	**0.000**	
C1	8/1/03 12:16	27.91	**0.000**	0.000	**0.000**	
C1	8/4/03 11:44	30.88	**0.000**	0.000	**0.000**	
C1	8/13/03 10:52	39.85	**0.000**	0.000	**0.001**	
C1	8/22/03 10:48	48.84	**0.000**	0.000	**0.000**	
C1	9/8/03 14:24	65.99	**0.000**	0.000	**0.000**	
C1	9/19/03 14:54	77.02	**0.000**	0.000	**0.003**	

Well ID	Date/Time	Days	SF6 Ave	SD	Fl Ave	SD
C2	7/4/03 9:18	-0.22	**0.039**	0.005	**0.000**	
C2	7/4/03 16:40	0.09	**1.554**	0.007	**0.000**	
C2	7/4/03 18:12	0.15	**0.149**	0.001	**0.000**	
C2	7/4/03 20:28	0.25	**0.000**	0.000	**0.000**	
C2	7/4/03 23:40	0.38	**0.659**	0.003	**0.000**	
C2	7/5/03 2:44	0.51	**0.517**	0.004	**-0.003**	
C2	7/5/03 6:24	0.66	**0.000**	0.000	**0.002**	
C2	7/5/03 10:22	0.83	**0.197**	0.001	**0.001**	
C2	7/5/03 14:44	1.01	**0.175**	0.001	**0.000**	
C2	7/5/03 20:10	1.23	**0.230**	0.005	**0.000**	
C2	7/6/03 2:18	1.49	**0.018**	0.018	**0.000**	
C2	7/6/03 8:16	1.74	**0.016**	0.008	**0.000**	
C2	7/6/03 14:24	1.99	**0.083**	0.003	**0.000**	
C2	7/6/03 20:18	2.24	**0.213**	0.005	**0.001**	
C2	7/7/03 4:50	2.60	**0.162**	0.003	**0.000**	
C2	7/7/03 11:20	2.87	**0.176**	0.005	**0.000**	
C2	7/8/03 10:54	3.85	**0.116**	0.004	**0.000**	
C2	7/9/03 11:38	4.88	**0.037**	0.002	**0.000**	
C2	7/10/03 11:50	5.89	**0.056**	0.007	**0.001**	
C2	7/11/03 12:48	6.93	**0.031**	0.008	**0.000**	
C2	7/12/03 16:44	8.09	**0.000**	0.000	**0.000**	
C2	7/13/03 13:26	8.95	**0.000**	0.000	**0.000**	
C2	7/14/03 12:08	9.90	**0.000**	0.000	**0.000**	
C2	7/18/03 13:04	13.94	**0.000**	0.000	**0.000**	
C2	7/21/03 15:52	17.06	**0.000**	0.000	**0.000**	
C2	7/24/03 14:38	20.00	**0.000**	0.000	**0.000**	
C2	7/28/03 11:18	23.87	**0.000**	0.000	**0.000**	
C2	8/1/03 12:04	27.90	**0.000**	0.000	**0.000**	
C2	8/4/03 11:32	30.88	**0.000**	0.000	**0.000**	
C2	8/13/03 10:40	39.84	**0.000**	0.000	**0.000**	
C2	8/22/03 10:34	48.83	**0.000**	0.000	**0.000**	
C2	9/8/03 14:12	65.99	**0.028**	0.001	**0.000**	
C2	9/19/03 2:38	76.50	**0.021**	0.001	**0.000**	

Well ID	Date/Time	Days	SF6 Ave	SD	Fl Ave	SD
C3	7/4/03 8:44	-0.24	**0.055**	0.002	**0.000**	
C3	7/4/03 16:02	0.06	**3.504**	0.010	**0.000**	
C3	7/4/03 17:26	0.12	**0.444**	0.012	**0.000**	
C3	7/4/03 19:56	0.22	**0.043**	0.000	**0.001**	
C3	7/4/03 23:00	0.35	**0.910**	0.003	**0.000**	
C3	7/5/03 2:12	0.49	**0.744**	0.001	**0.000**	
C3	7/5/03 6:38	0.67	**0.027**	0.009	**0.000**	
C3	7/5/03 10:40	0.84	**0.269**	0.009	**0.000**	
C3	7/5/03 15:08	1.03	**0.223**	0.008	**0.001**	
C3	7/5/03 20:24	1.24	**0.329**	0.006	**0.001**	
C3	7/6/03 2:32	1.50	**0.207**	0.004	**0.000**	
C3	7/6/03 8:30	1.75	**0.029**	0.003	**0.000**	
C3	7/6/03 14:40	2.01	**0.134**	0.002	**0.000**	
C3	7/6/03 20:32	2.25	**0.152**	0.012	**0.000**	
C3	7/7/03 5:04	2.61	**0.258**	0.002	**0.000**	
C3	7/7/03 11:34	2.88	**0.169**	0.004	**0.000**	
C3	7/8/03 11:06	3.86	**0.157**	0.003	**0.001**	
C3	7/9/03 11:54	4.89	**0.049**	0.009	**0.001**	
C3	7/10/03 12:06	5.90	**0.096**	0.008	**0.001**	
C3	7/11/03 13:04	6.94	**0.005**	0.006	**0.002**	
C3	7/12/03 16:56	8.10	**0.010**	0.014	**0.002**	
C3	7/13/03 13:40	8.96	**0.027**	0.005	**0.001**	
C3	7/14/03 11:56	9.89	**0.036**	0.016	**0.001**	
C3	7/18/03 13:30	13.96	**0.000**	0.000	**0.001**	
C3	7/21/03 16:26	17.08	**0.027**	0.003	**0.000**	
C3	7/24/03 15:02	20.02	**0.050**	0.017	**0.002**	
C3	7/28/03 11:06	23.86	**0.024**	0.010	**0.002**	
C3	8/1/03 12:30	27.92	**0.028**	0.013	**0.001**	
C3	8/4/03 11:58	30.89	**0.000**	0.000	**0.000**	
C3	8/13/03 11:06	39.86	**0.000**	0.000	**0.001**	
C3	8/22/03 10:44	48.84	**0.000**	0.000	**0.000**	
C3	9/8/03 14:40	66.01	**0.069**	0.012	**0.000**	
C3	9/19/03 15:10	77.03	**0.033**	0.002	**0.000**	

Well ID	Date/Time	Days	SF6 Ave	SD	Fl Ave	SD
C4	7/4/03 9:24	-0.21	**0.042**	0.000	**0.000**	
C4	7/4/03 16:20	0.07	**1.990**	0.002	**0.000**	
C4	7/4/03 18:30	0.17	**0.105**	0.002	**0.000**	
C4	7/4/03 20:44	0.26	**0.020**	0.000	**0.000**	
C4	7/5/03 0:18	0.41	**0.710**	0.015	**0.000**	
C4	7/5/03 3:00	0.52	**0.665**	0.000	**0.000**	
C4	7/5/03 6:10	0.65	**0.000**	0.000	**0.000**	
C4	7/5/03 10:02	0.81	**0.184**	0.002	**0.001**	
C4	7/5/03 14:18	0.99	**0.161**	0.015	**0.000**	
C4	7/5/03 19:56	1.22	**0.151**	0.003	**0.012**	
C4	7/6/03 2:02	1.48	**0.005**	0.007	**0.001**	
C4	7/6/03 8:02	1.73	**0.136**	0.004	**0.000**	
C4	7/6/03 14:10	1.98	**0.123**	0.005	**0.000**	
C4	7/6/03 20:04	2.23	**0.250**	0.002	**0.000**	
C4	7/7/03 4:20	2.57	**0.194**	0.005	**0.000**	
C4	7/7/03 11:04	2.86	**0.193**	0.000	**0.000**	
C4	7/8/03 10:42	3.84	**0.130**	0.000	**0.000**	
C4	7/9/03 11:22	4.87	**0.042**	0.000	**0.002**	
C4	7/10/03 11:34	5.88	**0.075**	0.007	**0.000**	
C4	7/11/03 12:32	6.92	**0.000**	0.000	**0.000**	
C4	7/12/03 16:32	8.08	**0.026**	0.002	**0.001**	
C4	7/13/03 13:12	8.94	**0.026**	0.001	**0.000**	
C4	7/14/03 12:20	9.91	**0.031**	0.006	**0.000**	
C4	7/16/03 15:14	12.03	**0.000**	0.000	**0.000**	
C4	7/18/03 12:50	13.93	**0.000**	0.000	**0.000**	
C4	7/21/03 15:38	17.05	**0.000**	0.000	**0.000**	
C4	7/24/03 14:28	20.00	**0.036**	0.001	**0.001**	
C4	7/28/03 11:34	23.88	**0.000**	0.000	**0.000**	
C4	8/1/03 11:48	27.89	**0.063**	0.005	**0.001**	
C4	8/4/03 11:10	30.86	**0.061**	0.002	**0.000**	
C4	8/13/03 10:26	39.83	**0.071**	0.008	**0.000**	
C4	8/22/03 10:26	48.83	**0.079**	0.004	**0.000**	
C4	9/8/03 13:58	65.98	**0.082**	0.001	**0.000**	
C4	9/19/03 14:22	76.99	**0.084**	0.010	**0.000**	

Well ID	Date/Time	Days	SF6 Ave	SD	Fl Ave	SD
C5	7/4/03 8:22	-0.26	**0.076**	0.002	**0.009**	
C5	7/4/03 15:46	0.05	**6.264**	0.032	**0.001**	
C5	7/4/03 17:08	0.11	**0.699**	0.004	**0.004**	
C5	7/4/03 19:40	0.21	**0.065**	0.005	**0.004**	
C5	7/4/03 22:40	0.34	**0.826**	0.010	**0.000**	
C5	7/5/03 3:16	0.53	**0.731**	0.001	**0.000**	
C5	7/5/03 7:18	0.70	**0.028**	0.001	**0.000**	
C5	7/5/03 11:36	0.88	**0.216**	0.001	**0.000**	
C5	7/5/03 16:12	1.07	**0.226**	0.002	**0.000**	
C5	7/5/03 21:02	1.27	**0.221**	0.001	**0.005**	
C5	7/6/03 3:12	1.53	**0.174**	0.000	**0.002**	
C5	7/6/03 9:08	1.78	**0.023**	0.001	**0.018**	
C5	7/6/03 15:16	2.03	**0.000**	0.000	**0.000**	
C5	7/6/03 21:14	2.28	**0.250**	0.016	**0.002**	
C5	7/7/03 5:44	2.63	**0.240**	0.001	**0.001**	
C5	7/7/03 12:16	2.91	**0.198**	0.021	**0.000**	
C5	7/8/03 11:44	3.88	**0.102**	0.003	**0.000**	
C5	7/9/03 12:52	4.93	**0.034**	0.000	**0.000**	
C5	7/10/03 12:54	5.93	**0.093**	0.010	**0.019**	
C5	7/11/03 13:36	6.96	**0.036**	0.002	**0.001**	
C5	7/12/03 17:28	8.12	**0.025**	0.005	**0.000**	
C5	7/13/03 14:26	9.00	**0.042**	0.003	**0.000**	
C5	7/14/03 11:16	9.86	**0.058**	0.001	**0.000**	
C5	7/18/03 13:56	13.97	**0.235**	0.006	**0.012**	
C5	7/21/03 16:54	17.10	**0.446**	0.000	**0.000**	
C5	7/24/03 15:26	20.04	**0.288**	0.001	**0.001**	
C5	7/28/03 13:20	23.95	**0.525**	0.005	**0.005**	
C5	8/1/03 13:10	27.94	**0.731**	0.003	**0.054**	0.002
C5	8/4/03 12:40	30.92	**0.601**	0.002	**0.043**	0.003
C5	8/13/03 11:28	39.87	**0.894**	0.000	**0.073**	
C5	8/22/03 11:04	48.86	**0.829**	0.017	**0.044**	
C5	9/8/03 14:52	66.01	**0.716**	0.001	**0.061**	
C5	9/19/03 15:22	77.03	**1.111**	0.003	**0.000**	
C5	10/10/03 13:12	97.94	**0.270**	0.001	**0.001**	
C5	12/3/2003 12:02	151.90	**0.319**	0.014	**0.000**	
C5	5/10/04 13:12	310.94	**0.158**	0.046	**0.003**	

Well ID	Date/Time	Days	SF6 Ave	SD	Fl Ave	SD
C6	7/3/03 20:14	-0.76	**0.062**	0.019	**0.000**	
C6	7/4/03 15:36	0.04	**8.154**	0.012	**0.000**	
C6	7/4/03 16:50	0.10	**1.048**	0.003	**0.000**	
C6	7/4/03 19:00	0.19	**0.087**	0.005	**0.000**	
C6	7/4/03 21:20	0.28	**1.047**	0.009	**0.006**	
C6	7/5/03 0:54	0.43	**0.899**	0.005	**0.000**	
C6	7/5/03 4:54	0.60	**0.085**	0.096	**0.000**	
C6	7/5/03 8:54	0.77	**0.030**	0.010	**0.015**	
C6	7/5/03 18:56	1.18	**1.031**	0.014	**0.009**	
C6	7/6/03 0:58	1.43	**0.117**	0.001	**0.022**	
C6	7/6/03 7:02	1.69	**0.119**	0.002	**0.012**	
C6	7/6/03 12:58	1.93	**0.138**	0.001	**0.030**	
C6	7/6/03 19:00	2.19	**0.000**	0.000	**0.021**	
C6	7/7/03 3:14	2.53	**0.222**	0.006	**0.014**	
C6	7/7/03 9:58	2.81	**0.240**	0.011	**0.020**	
C6	7/8/03 9:50	3.80	**0.055**	0.001	**0.039**	
C6	7/10/03 10:24	5.83	**0.107**	0.002	**0.027**	
C6	7/11/03 11:10	6.86	**0.147**	0.001	**0.024**	
C6	7/12/03 15:40	8.05	**0.123**	0.004	**0.011**	
C6	7/13/03 12:10	8.90	**0.251**	0.015	**0.011**	
C6	7/14/03 10:36	9.84	**0.294**	0.005	**0.008**	
C6	7/16/03 14:56	12.02	**0.285**	0.004	**0.012**	
C6	7/18/03 12:36	13.92	**0.429**	0.010	**0.012**	
C6	7/21/03 15:26	17.04	**0.563**	0.006	**0.015**	
C6	7/24/03 14:18	19.99	**0.281**	0.001	**0.007**	
C6	7/28/03 12:36	23.92	**0.810**	0.003	**0.010**	
C6	8/1/03 11:32	27.88	**0.824**	0.012	**0.009**	
C6	8/4/03 10:58	30.85	**0.800**	0.002	**0.009**	
C6	8/13/03 9:58	39.81	**1.018**	0.003	**0.004**	
C6	8/22/03 10:10	48.82	**0.721**	0.005	**0.003**	
C6	9/8/03 13:28	65.96	**1.200**	0.148	**0.002**	
C6	9/19/03 14:04	76.98	**0.537**	0.010	**0.001**	
C6	10/10/03 13:08	97.94	**0.383**	0.005	**0.113**	
C6	12/3/2003 11:36	151.88	**0.094**	0.013	**0.001**	

Well ID	Date/Time	Days	SF6 Ave	SD	Fl Ave	SD
Spring	7/4/03 10:36	-0.16	**0.028**	0.003	**0.000**	
Spring	7/4/03 18:58	0.18	**0.514**	0.029	**0.000**	
Spring	7/5/03 8:06	0.73	**0.243**	0.012	**0.001**	
Spring	7/5/03 17:28	1.12	**0.360**	0.073	**0.000**	
Spring	7/6/03 10:36	1.84	**0.492**	0.099	**0.000**	
Spring	7/6/03 20:44	2.26	**0.106**	0.003	**0.000**	
Spring	7/7/03 13:26	2.95	**0.194**	0.003	**0.001**	
Spring	7/9/03 15:46	5.05	**0.032**	0.004	**0.000**	
Spring	7/10/03 13:38	5.96	**0.102**	0.002	**0.000**	
Spring	7/11/03 14:26	7.00	**0.034**	0.001	**0.000**	
Spring	7/12/03 14:30	8.00	**0.025**	0.005	**0.000**	
Spring	7/13/03 15:06	9.02	**0.000**	0.000	**0.000**	
Spring	7/14/03 12:46	9.93	**0.000**	0.000	**0.000**	
Spring	7/16/03 13:16	11.95	**-**	-	**0.000**	
Spring	7/18/03 14:34	14.00	**0.000**	0.000	**0.000**	
Spring	7/21/03 17:20	17.12	**0.000**	0.000	**0.000**	
Spring	7/24/03 15:44	20.05	**0.000**	0.000	**0.008**	
Spring	7/28/03 14:00	23.98	**0.007**	0.010	**0.000**	
Spring	8/1/03 16:18	28.07	**0.000**	0.000	**0.004**	
Spring	8/4/03 13:06	30.94	**0.000**	0.000	**-**	
Spring	8/13/03 12:02	39.90	**0.000**	0.000	**0.001**	
Spring	9/8/03 15:28	66.04	**0.000**	0.000	**0.000**	
Spring	9/19/03 15:56	77.06	**0.000**	0.000	**0.001**	

Well ID	Date/Time	Days	SF6 Ave	SD	Fl Ave	SD
Catfish	7/4/03 10:24	-0.17	**0.037**	0.005	**0.000**	
Catfish	7/4/03 18:32	0.17	**0.765**	0.000	**0.002**	
Catfish	7/5/03 7:52	0.72	**0.433**	0.001	**0.000**	
Catfish	7/5/03 17:10	1.11	**0.186**	0.003	**0.000**	
Catfish	7/6/03 9:58	1.81	**0.304**	0.002	**0.000**	
Catfish	7/6/03 20:26	2.25	**0.114**	0.004	**0.000**	
Catfish	7/7/03 13:16	2.95	**0.199**	0.005	**0.000**	
Catfish	7/9/03 15:24	5.04	**0.035**	0.001	**0.000**	
Catfish	7/10/03 13:24	5.95	**0.028**	0.004	**0.000**	
Catfish	7/11/03 14:16	6.99	**0.036**	0.002	**0.000**	
Catfish	7/12/03 14:56	8.02	**0.029**	0.000	**0.000**	
Catfish	7/13/03 14:48	9.01	**0.010**	0.014	**0.000**	
Catfish	7/14/03 12:36	9.92	**0.000**	0.000	**0.000**	
Catfish	7/16/03 13:10	11.94	**-**	-	**0.001**	
Catfish	7/18/03 14:26	14.00	**0.000**	0.000	**0.000**	
Catfish	7/21/03 17:14	17.11	**0.000**	0.000	**0.000**	
Catfish	7/24/03 15:40	20.05	**0.000**	0.000	**0.017**	
Catfish	7/28/03 13:40	23.96	**0.000**	0.000	**0.000**	
Catfish	8/1/03 16:08	28.07	**0.000**	0.000	**0.000**	
Catfish	8/4/03 13:00	30.94	**0.000**	0.000	**0.001**	
Catfish	8/13/03 11:48	39.89	**0.000**	0.000	**0.000**	
Catfish	9/8/03 15:14	66.03	**0.000**	0.000	**0.002**	
Catfish	9/19/03 15:46	77.05	**0.000**	0.000	**0.003**	
Sue Sink	7/4/03 10:08	-0.18	**0.060**	0.006	**0.004**	
Sue Sink	7/4/03 18:06	0.15	**0.975**	0.008	**0.000**	
Sue Sink	7/5/03 7:32	0.71	**0.530**	0.007	**0.000**	
Sue Sink	7/5/03 16:50	1.10	**0.382**	0.005	**0.000**	
Sue Sink	7/6/03 9:38	1.80	**0.320**	0.006	**0.000**	
Sue Sink	7/6/03 20:00	2.23	**0.103**	0.001	**0.000**	
Sue Sink	7/7/03 13:00	2.94	**0.208**	0.001	**0.000**	
Sue Sink	7/9/03 15:14	5.03	**0.027**	0.006	**0.000**	
Taken between 11:15 and 11:30 at different points inside cave, 500-100 ft from spring						
Cave	7/6/03 11:30	1.87	**0.131**	0.001	**0.000**	
Cave	7/6/03 11:30	1.87	**0.130**	0.014	**0.000**	
Cave	7/6/03 11:30	1.87	**0.305**	0.003	**0.000**	
Cave	7/6/03 11:30	1.87	**0.194**	0.005	**0.000**	
Cave	7/6/03 11:30	1.87	**0.276**	0.006	**-**	
Cave	7/6/03 11:30	1.87	**0.276**	0.006	**-**	

Appendix 2

Nutient and Fecal Coliform Data

Appendix 2a. Magnolia Nutrient and Fecal Coliform data.

	Time	Water Table Elevation	Total Phosphorus	Total Nitrogen	Nitrate	Nitrite	TKN	Total Ammonia	Fecal Coliforms
Units:		ft	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	# colonies /100 mL
Method:			EPA 365.3	Calculated	EPA 353.3	SM 4500NO2B	EPA 351.3	EPA 350.2	SM 9222D
Detection Limit:			0.014		0.012	0.012	0.071	0.067	2
M1	2/20/03 12:11	2.56	0.348	19.1	18.5	< 0.012	0.631	0.236	< 2
M1 dup	2/20/03 12:13		0.314	18.4	17.9	< 0.012	0.533	0.26	< 2
M1	4/1/03 11:45	8.53	0.202	23	22.6	< 0.012	0.484	0.342	< 2
M1	5/20/03 9:45	3.81	0.33	24.6	23.1	< 0.012	1.49	0.968	< 2
M1	7/7/03 10:00	4.12	0.297	24.9	24.2	< 0.012	0.673	0.589	2
M1	8/22/03 12:20	4.74	0.423	65.4	63.1	< 0.012	2.33	1.41	4
M1dup	8/22/03 12:20		0.48	38.9	36.5	< 0.012	2.44	1.46	4
M1	10/10/03 12:06	3.25	0.435	35.2	33.9	< 0.012	1.25	1.01	< 2
M1	12/3/03 10:42	2.15	0.545	35.8	34	< 0.012	1.77	1.02	< 2
M1	1/26/2004 12:38	2.26	0.17	33.6	29.8	0.078	3.84	2.53	< 2
M1	5/10/2004 12:08	2.13	0.363	40.2	38.1	< 0.012	2.1	1.76	< 2

	Time	Water Table Elevation	Total Phosphorus	Total Nitrogen	Nitrate	Nitrite	TKN	Total Ammonia	Fecal Coliforms
Units:		ft	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	# colonies /100 mL
Method:			EPA 365.3	Calculated	EPA 353.3	SM 4500NO2B	EPA 351.3	EPA 350.2	SM 9222D
Detection Limit:			0.014		0.012	0.012	0.071	0.067	2
M2	2/20/03 11:58	2.63	0.987	22.4	22	< 0.012	0.347	< 0.067	< 2
M2	4/1/03 12:00	8.66	0.502	10.4	10.2	< 0.012	0.264	< 0.067	2
M2 dup	4/1/03 11:58		0.544	7.25	7.13	< 0.012	0.125	< 0.067	< 2
M2	5/20/03 9:55	3.77	0.246	8.1	7.7	< 0.012	0.355	0.296	< 2
M2	7/7/03 9:48	4.12	0.675	15.6	15	0.038	0.611	0.599	41
M2	8/22/03 12:12	4.79	0.724	64.1	63.2	0.013	0.932	0.619	14
M2	10/10/03 11:46	3.25	0.728	8.56	8.33	< 0.012	0.226	0.197	< 2
M2 dup	10/10/03 11:46		0.773	9.22	9.06	< 0.012	0.161	0.133	6
M2	12/3/03 10:28	2.17	0.76	19.9	19.7	< 0.012	0.169	< 0.067	< 2
M2 dup	12/3/03 10:28		0.841	21.7	21.5	< 0.012	0.157	< 0.067	< 2
M2	1/26/04 11:48	2.26	1.26	33.7	33.5	< 0.012	0.187	0.125	82
M2	5/10/2004 11:44	2.13	0.886	25.9	25.8	< 0.012	0.095	0.072	< 2

	Time	Water Table Elevation	Total Phosphorus	Total Nitrogen	Nitrate	Nitrite	TKN	Total Ammonia	Fecal Coliforms
Units:		ft	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	# colonies /100 mL
Method:			EPA 365.3	Calculated	EPA 353.3	SM 4500NO2B	EPA 351.3	EPA 350.2	SM 9222D
Detection Limit:			0.014		0.012	0.012	0.071	0.067	2
M3	2/20/03 11:09	3.07	0.366	1.58	0.92	< 0.012	0.655	< 0.067	< 2
M3	5/20/03 10:07	4.22	0.48	7.48	6.57	< 0.012	0.911	0.717	< 2
M3	7/7/03 10:50	4.56	0.548	12	11.7	< 0.012	0.302	0.298	35
M3	8/22/03 11:46	5.24	0.6	34.7	33.9	0.013	0.754	0.256	24
M3	10/10/03 11:10	3.69	0.666	4.87	4.41	0.016	0.456	0.128	< 2
M3	12/3/03 9:30	2.61	0.729	16	16	0.065	< 0.071	< 0.067	6
M3	1/26/2004 11:38	2.74	0.481	22.8	22.8	0.028	< 0.071	< 0.067	22
M3	5/10/2004 11:12	2.61	0.458	22.9	22.8	0.036	0.087	0.074	< 2
M4	2/20/03 10:28	2.59	0.188	0.601	0.196	< 0.012	0.405	< 0.067	< 2
M4	5/20/03 10:40	3.68	0.76	0.333	0.131	< 0.012	0.212	0.144	< 2
M4	7/7/03 11:00	4.05	< 0.014	0.246	0.14	< 0.012	0.106	0.1	< 2
M4	8/22/03 11:42	4.73	0.032	0.476	0.16	< 0.012	0.316	0.102	4
M4	10/10/03 11:00	3.17	< 0.014	0.593	0.029	< 0.012	0.564	0.142	10
M4	12/3/03 9:18	2.09	< 0.014	0.376	0.206	< 0.012	0.17	0.096	< 2
M4	1/26/2004 11:20	2.30	< 0.014	0.711	0.356	< 0.012	0.355	0.137	< 2
M4	5/10/2004 10:58	2.13	< 0.014	1.09	0.774	< 0.012	0.313	0.138	< 2

	Time	Water Table Elevation	Total Phosphorus	Total Nitrogen	Nitrate	Nitrite	TKN	Total Ammonia	Fecal Coliforms
Units:		ft	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	# colonies /100 mL
Method:			EPA 365.3	Calculated	EPA 353.3	SM 4500NO2B	EPA 351.3	EPA 350.2	SM 9222D
Detection Limit:			0.014		0.012	0.012	0.071	0.067	2
M5	2/20/03 11:25	2.60	1.14	22.5	21.9	< 0.012	0.568	0.515	10
M5	5/20/03 10:05	3.68	0.16	16.1	15.3	< 0.012	0.827	0.742	< 2
M5	7/7/03 10:12	4.08	0.12	17.8	16.9	< 0.012	0.888	0.829	7
M5	8/22/03 12:08	4.67	0.145	62.6	61.6	< 0.012	0.992	0.663	< 2
M5	10/10/03 11:38	3.19	0.126	21.7	21	< 0.012	0.651	0.592	4
M5	12/3/03 10:14	2.08	0.144	25.6	24.6	< 0.012	1.04	0.547	159
M5	1/26/04 12:20	2.21	< 0.014	17.3	16.5	< 0.012	0.822	0.552	< 2
M5 dup	1/26/04 12:20		< 0.014	17.6	16.4	< 0.012	1.17	0.749	< 2
M5	5/10/2004 11:54	2.11	0.076	31.5	30.8	< 0.012	0.66	0.59	< 2
M6	2/20/03 10:40	2.57	0.915	6.58	6.11	< 0.012	0.466	< 0.067	< 2
M6	5/20/03 10:35	3.63	0.035	11.6	11.2	< 0.012	0.37	0.357	< 2
M6 dup	5/20/03 10:36		0.03	8.85	8.39	< 0.012	0.457	0.36	< 2
M6	7/7/03 10:38	4.03	< 0.014	23.7	23.5	< 0.012	0.223	0.216	5
M6	8/22/03 11:56	4.67	0.065	51.4	51.1	0.014	0.308	0.278	114
M6	10/10/03 11:20	3.14	0.022	11.8	11.5	< 0.012	0.341	0.255	< 2
M6	12/3/03 9:40	2.03	< 0.014	12.5	12.2	< 0.012	0.271	0.193	< 2
M6	1/26/2004 11:44	2.29	< 0.014	11.4	11.2	< 0.012	0.237	0.155	< 2
M6	5/10/2004 11:22	2.11	< 0.014	15	14.8	0.012	0.213	0.18	< 2

Units:	Time	Water Table Elevation ft	Total Phosphorus mg/L	Total Nitrogen mg/L	Nitrate mg/L	Nitrite mg/L	TKN mg/L	Total Ammonia mg/L	Fecal Coliforms # colonies /100 mL
Method:			EPA 365.3	Calculated	EPA 353.3	SM 4500NO2B	EPA 351.3	EPA 350.2	SM 9222D
Detection Limit:			0.014		0.012	0.012	0.071	0.067	2
M7	2/20/03 10:53	3.57	1.24	9.86	9.55	< 0.012	0.304	0.169	< 2
M7	5/20/03 10:20	4.69	0.484	11.5	11.1	< 0.012	0.399	0.386	< 2
M7	7/7/03 10:26	5.05	0.271	13.5	13.1	< 0.012	0.441	0.423	3
M7	8/22/03 12:00	5.71	0.36	63.3	62.8	0.021	0.506	0.239	54
M7	10/10/03 11:28	4.18	0.294	13.9	13.6	0.017	0.321	0.233	< 2
M7	12/3/03 9:52	3.07	< 0.014	14.4	14.1	0.023	0.281	0.193	< 2
M7	1/26/04 12:10	3.25	< 0.014	12.8	12.3	< 0.012	0.463	0.315	< 2
M7	5/10/2004 11:30	3.10	0.107	18.6	18.4	< 0.012	0.203	0.143	< 2
M8	2/20/03 11:43	2.61	1.05	21.2	19.6	< 0.012	1.56	0.77	36
M8	5/20/03 9:50	3.76	0.638	8.1	5.9	< 0.012	2.2	1.66	932
M8	7/7/03 9:36	4.12	0.861	33.9	31.6	< 0.012	2.25	2.18	12
M8 Dup	7/7/03 9:36		0.815	30.7	30.5	< 0.012	0.238	0.221	< 2
M8	8/22/03 12:30	4.75	0.671	67.5	65	< 0.012	2.54	1.41	< 2
M8 dup	8/22/03 12:30		0.97	46.7	44.2	< 0.012	2.45	1.46	< 2
M8	10/10/03 11:56	3.25	0.773	9.89	9.51	0.016	0.381	0.344	6
M8	12/3/03 10:56	2.15	1.2	38.7	37	< 0.012	1.74	1.39	< 2
M8	1/26/2004 12:50	2.25	0.798	46.4	44.7	< 0.012	1.66	1.14	< 2
M8	5/10/2004 12:16	2.12	1.36	38.9	37.9	< 0.012	0.965	0.962	< 2
M8 dup	5/10/2004 12:16		1.28	39.3	38.3	< 0.012	1.01	0.933	< 2

Units:	Time	Water Table Elevation ft	Total Phosphorus mg/L	Total Nitrogen mg/L	Nitrate mg/L	Nitrite mg/L	TKN mg/L	Total Ammonia mg/L	Fecal Coliforms # colonies /100 mL
Method:			EPA 365.3	Calculated	EPA 353.3	SM 4500NO2B	EPA 351.3	EPA 350.2	SM 9222D
Detection Limit:			0.014		0.012	0.012	0.071	0.067	2
M9	2/20/03 10:05	2.56	0.148	1.09	0.96	< 0.012	0.132	< 0.067	< 2
M9	5/20/03 10:18	3.74	< 0.014	0.618	0.295	< 0.012	0.323	< 0.067	< 2
M9	7/7/03 11:16	4.10	< 0.014	1.37	0.933	< 0.012	0.432	0.431	61
M9	8/22/03 10:32	4.76	0.126	1.33	0.709	< 0.012	0.62	0.308	2
M9	10/10/03 10:50	3.22	< 0.014	0.552	0.032	< 0.012	0.52	0.137	< 2
M9	12/3/03 9:08	2.13	< 0.014	3.05	2.52	< 0.012	0.531	0.181	< 2
M9	1/26/2004 11:05	2.28	< 0.014	14.6	13.8	< 0.012	0.832	0.613	< 2
M9	5/10/2004 10:46	2.13	< 0.014	36.2	35.9	< 0.012	0.273	0.219	< 2
M10	2/20/03 9:51	2.59	0.027	0.687	0.061	< 0.012	0.626	0.262	< 2
M10	5/20/03 10:30	3.74	< 0.014	0.153	< 0.012	< 0.012	0.153	0.075	< 2
M10	7/7/03 11:30	4.00	< 0.014	0.171	0.038	< 0.012	0.133	< 0.067	< 2
M10	8/22/03 10:30	4.75	0.049	0.243	0.016	< 0.012	0.227	< 0.067	< 2
M10	10/10/03 10:44	3.21	< 0.014	0.468	< 0.012	< 0.012	0.468	0.128	12
M10	12/3/03 8:56	2.18	< 0.014	0.8	0.146	< 0.012	0.658	0.44	10
M10	1/26/2004 10:50	2.31	< 0.014	0.301	< 0.012	< 0.012	0.301	0.1	< 2
M10	5/10/2004 10:38	2.16	< 0.014	0.481	< 0.012	< 0.012	0.481	0.083	6

Appendix 2b. Hickory Nutrient and Fecal Coliform data.

	Time	Water Table Elevation	Total Phosphorus	Total Nitrogen	Nitrate	Nitrite	TKN	Total Ammonia	Fecal Coliforms
Units:		ft	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	# colonies /100 mL
Method:			EPA 365.3	Calculated	EPA 353.3	SM 4500NO2B	EPA 351.3	EPA 350.2	SM 9222D
Detection Limit:			0.014		0.012	0.012	0.071	0.067	2
C1	2/19/03 12:32	2.24	< 0.014	0.93	0.59	< 0.012	0.334	< 0.067	< 2
C1dup	2/19/03 12:34		0.032	1.04	0.844	< 0.012	0.192	0.099	< 2
C1	4/1/03 10:45	8.74	< 0.014	0.59	0.389	< 0.012	0.201	< 0.067	< 2
C1	5/20/03 12:25	3.39	< 0.014	0.221	0.112	< 0.012	0.109	< 0.067	< 2
C1	7/7/03 11:50	4.03	< 0.014	0.236	0.236	< 0.012	< 0.071	< 0.067	< 2
C1	8/22/03 10:48	4.80	< 0.014	0.722	0.512	< 0.012	0.21	< 0.067	2
C2	2/19/03 11:49	2.18	< 0.014	1.61	0.285	< 0.012	1.32	< 0.067	< 2
C2	4/1/03 10:50	8.61	< 0.014	0.857	0.74	< 0.012	0.117	< 0.067	< 2
C2	5/20/03 12:20	3.33	< 0.014	0.556	0.433	< 0.012	0.123	< 0.067	< 2
C2	7/7/03 11:20	3.92	< 0.014	0.352	0.352	< 0.012	< 0.071	< 0.067	< 2
C2	8/22/03 10:34	4.71	< 0.014	0.7	0.591	< 0.012	0.109	< 0.067	< 2
C3A	2/19/03 12:03	2.13	0.025	0.802	0.384	< 0.012	0.418	< 0.067	< 2
C3A	4/1/03 11:05	8.59	< 0.014	1.1	1.1	< 0.012	< 0.071	< 0.067	< 2
C3A	5/20/03 12:20	3.31	0.047	0.484	0.374	< 0.012	0.11	< 0.067	< 2
C3A	7/7/03 11:34	3.92	< 0.014	0.477	0.477	< 0.012	< 0.071	< 0.067	7
C3A	8/22/03 10:44	4.69	< 0.014	0.702	0.602	< 0.012	0.1	< 0.067	< 2

	Time	Water Table Elevation	Total Phosphorus	Total Nitrogen	Nitrate	Nitrite	TKN	Total Ammonia	Fecal Coliforms
Units:		ft	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	# colonies /100 mL
Method:			EPA 365.3	Calculated	EPA 353.3	SM 4500NO2B	EPA 351.3	EPA 350.2	SM 9222D
Detection Limit:			0.014		0.012	0.012	0.071	0.067	2
C4	2/19/03 11:34	2.15	0.027	0.796	0.443	< 0.012	0.353	< 0.067	< 2
C4	4/1/03 10:25	8.60	< 0.014	1.23	1.23	< 0.012	< 0.071	< 0.067	< 2
C4	5/20/03 12:03	3.29	0.023	0.691	0.602	< 0.012	0.089	< 0.067	< 2
C4	7/7/03 11:00	3.91	< 0.014	0.451	0.451	< 0.012	< 0.071	< 0.067	< 2
C4	8/22/03 10:26	4.70	0.02	0.935	0.823	< 0.012	0.112	< 0.067	10
C5	2/19/03 12:17	2.26	0.131	2.31	1.94	< 0.012	0.366	0.214	< 2
C5	4/1/03 11:10	8.72	0.157	2.5	1.85	< 0.012	0.607	< 0.067	< 2
C5	5/20/03 12:05	4.36	0.167	3.9	3.32	< 0.012	0.587	< 0.067	6
C5	7/7/03 12:16	4.07	< 0.014	3.98	3.85	< 0.012	0.133	0.107	< 2
C5	8/22/03 11:04	4.82	< 0.014	41.3	41.3	0.018	< 0.071	< 0.067	< 2
C5	10/10/03 13:12	3.05	< 0.014	8.1	7.98	0.018	0.108	0.084	< 2
C5	12/3/2003 12:02	1.88	< 0.014	8.97	8.89	0.045	0.081	< 0.067	< 2
C5	1/26/2004 13:40	2.52	< 0.014	3.58	3.47	< 0.012	0.113	0.073	< 2
C5	5/10/2004 13:12	2.21	< 0.014	32.8	32.7	< 0.012	< 0.071	< 0.067	< 2

	Time	Water Table Elevation	Total Phosphorus	Total Nitrogen	Nitrate	Nitrite	TKN	Total Ammonia	Fecal Coliforms
Units:		ft	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	# colonies /100 mL
Method:			EPA 365.3	Calculated	EPA 353.3	SM 4500NO2 B	EPA 351.3	EPA 350.2	SM 9222D
Detection Limit:			0.014		0.012	0.012	0.071	0.067	2
C6	2/19/03 10:38	2.20	0.033	1.5	1.11	< 0.012	0.392	< 0.067	< 2
C6	4/1/03 10:15	8.73	< 0.014	1.51	1.51	< 0.012	< 0.071	< 0.067	< 2
C6	5/20/03 11:45	3.35	< 0.014	1.27	1.27	< 0.012	< 0.071	< 0.067	< 2
C6 dup	5/20/03 11:47		< 0.014	1.19	1.19	< 0.012	< 0.071	< 0.067	< 2
C6	7/7/03 9:58	4.02	< 0.014	1.45	1.22	< 0.012	0.233	0.201	24
C6 Dup	7/7/03 9:58		< 0.014	1.65	1.44	< 0.012	0.213	0.202	9
C6	8/22/03 10:10		< 0.014	1.96	1.96	< 0.012	< 0.071	< 0.067	4
C6	10/10/03 13:08	2.86	< 0.014	22.9	22.9	< 0.012	< 0.071	< 0.067	6
C6	12/3/2003 11:36	2.10	< 0.014	5.88	5.21	< 0.012	0.675	0.232	< 2

	Time	Water Table Elevation	Total Phosphorus	Total Nitrogen	Nitrate	Nitrite	TKN	Total Ammonia	Fecal Coliforms
Units:		ft	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	# colonies /100 mL
Method:			EPA 365.3	Calculated	EPA 353.3	SM 4500NO2 B	EPA 351.3	EPA 350.2	SM 9222D
Detection Limit:			0.014		0.012	0.012	0.071	0.067	2
S1	2/19/03 10:12	2.44	4.890	27.7	26.8	0.063	0.879	0.672	< 2
S1	4/1/03 11:20	8.79	1.090	22.2	21.8	0.027	0.335	0.334	< 2
S1 dup	4/1/03 11:20		1.100	18.6	18.1	0.027	0.477	0.407	< 2
S1	5/20/03 11:36	3.54	0.84	13.7	13.6	< 0.012	0.072	0.069	< 2
S1	7/7/03 9:45	4.08	0.906	20.8	20.3	< 0.012	0.547	0.524	99
S1	8/22/03 10:16	4.88	0.82	56.1	56.1	0.063	< 0.071	< 0.067	40
S1	10/10/03 12:54	3.10	0.829	12.3	12.3	0.029	< 0.071	< 0.067	< 2
S1	12/3/2003 11:50	1.96	0.763	7.99	7.77	< 0.012	0.218	0.128	< 2
S1 dup	1/26/2004 13:30		0.388	4.29	4.29	< 0.012	< 0.071	< 0.067	< 2
S1	1/26/2004 13:30	2.52	0.434	4.25	4.26	< 0.012	< 0.071	< 0.067	< 2
S1	5/10/2004 13:00	2.27	0.452	33.8	33.6	< 0.012	0.197	0.147	24
S1 dup	5/10/2004 13:02		0.485	38.4	38.3	< 0.012	0.08	< 0.067	22
S2	2/19/03 9:51	2.50	0.038	1.36	0.919	< 0.012	0.437	< 0.067	< 2
S2	4/1/03 10:40	8.83	< 0.014	1.06	1.06	< 0.012	< 0.071	< 0.067	< 2
S2	5/20/03 11:25	3.55	< 0.014	0.406	0.272	< 0.012	0.134	< 0.067	< 2
S2	7/7/03 10:14	4.14	< 0.014	0.632	0.312	< 0.012	0.32	0.124	< 2
S2	8/22/03 10:04	4.93	0.02	0.601	0.324	< 0.012	0.277	< 0.067	8

	Time	Water Table Elevation	Total Phosphorus	Total Nitrogen	Nitrate	Nitrite	TKN	Total Ammonia	Fecal Coliforms
Units:		ft	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	# colonies /100 mL
Method:			EPA 365.3	Calculated	EPA 353.3	SM 4500NO2 B	EPA 351.3	EPA 350.2	SM 9222D
Detection Limit:			0.014		0.012	0.012	0.071	0.067	2
S3	2/19/03 11:02	2.33	0.703	0.805	0.057	< 0.012	0.748	< 0.067	< 2
S3	4/1/03 9:55	8.68	0.144	0.283	0.075	< 0.012	0.208	< 0.067	< 2
S3	5/20/03 11:20	3.47	0.143	0.242	0.066	< 0.012	0.176	< 0.067	< 2
S3	7/7/03 10:44	3.97	< 0.014	0.162	0.055	< 0.012	0.107	< 0.067	74
S3	8/22/03 9:46	4.80	0.061	0.459	< 0.012	< 0.012	0.459	< 0.067	124
S4	2/19/03 9:28	2.36	0.260	1.18	0.489	< 0.012	0.687	< 0.067	< 2
S4	4/1/03 10:05	8.69	< 0.014	0.665	0.481	< 0.012	0.184	< 0.067	< 2
S4	5/20/03 11:32	3.41	0.047	0.357	0.19	< 0.012	0.167	< 0.067	< 2
S4	7/7/03 10:28	3.95	< 0.014	0.294	0.173	< 0.012	0.121	< 0.067	< 2
S4	8/22/03 9:48	4.75	0.068	0.494	0.078	< 0.012	0.416	< 0.067	6
CA1	2/21/03 11:14		0.022	0.439	0.115	< 0.012	0.324	0.134	< 2
CA1	4/1/2003 10:35		< 0.014	0.466	0.063	< 0.012	0.403	0.14	2
CA1	5/20/03 10:50		< 0.014	0.218	< 0.012	< 0.012	0.218	0.136	< 2
CA1	7/7/2003 10:35		< 0.014	0.192	0.02	< 0.012	0.172	0.123	< 2
CA1	8/22/2003 11:00		0.028	0.417	0.147	< 0.012	0.27	0.13	< 2

	Time	Water Table Elevation	Total Phosphorus	Total Nitrogen	Nitrate	Nitrite	TKN	Total Ammonia	Fecal Coliforms
Units:		ft	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	# colonies /100 mL
Method:			EPA 365.3	Calculated	EPA 353.3	SM 4500NO2 B	EPA 351.3	EPA 350.2	SM 9222D
Detection Limit:			0.014		0.012	0.012	0.071	0.067	2
MB2	2/21/03 10:15		0.474	1.81	1.61	< 0.012	0.199	< 0.067	< 2
MB2	4/1/2003 9:50		0.113	0.233	0.121	< 0.012	0.113	< 0.067	< 2
MB2	5/20/03 10:15		0.095	0.18	0.08	< 0.012	0.099	< 0.067	< 2
MB2	7/7/2003 10:50		0.035	0.045	0.045	< 0.012	< 0.071	< 0.067	< 2
MB2	8/22/2003 10:45		0.22	1.32	1.21	< 0.012	0.114	< 0.067	< 2